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A CYTOLOGICAL ANALYSIS OF A NATURALLY OCCURRING *HELIANTHUS* HYBRID

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One of the most interesting examples of natural hybridization in the genus *Helianthus* (family Compositae) is that involving *H. salicifolius* A. Dietr. and *H. grosseserratus* Martens. The first species is a perennial sunflower with tall, smooth stems bearing many drooping, alternate lance-linear leaves; the disk corollas may be either purple- or yellow-colored. It is found in dry prairies from Missouri to Texas but is sometimes cultivated in northeastern United States for its unusual foliage and showy flowers. The second species is a common weed that grows along roads and fencerows throughout much of the Midwest. The plant produces tall, generally smooth stems with ascending, alternate, lanceolate or lance-ovate leaves; the disk corollas are yellow. The hybrid of these species is *H.* × *Kellermani* Britton pro sp. named for Dr. W. A. Kellerman who first collected the plant near Columbus, Ohio, in 1897 (Kellerman, 1902). Since that time only a few collections have been made in widely separated places from Ohio to Wisconsin.

In the course of a previous investigation, an artificial F_1 hybrid was produced and compared morphologically and cytologically to a natural hybrid from Columbus, Ohio (Long, 1955). A preliminary study of microsporogenesis showed that irregularities were present in both hybrids. This report deals with the results of a detailed examination of microsporogenesis in a new collection (23) of putative *H.* × *Kellermani* from near Leonardsburg, Ohio, made in 1954. The investigation was undertaken primarily to obtain data with which to evaluate the taxonomic relationship of *H. salicifolius* and *H. grosseserratus*.

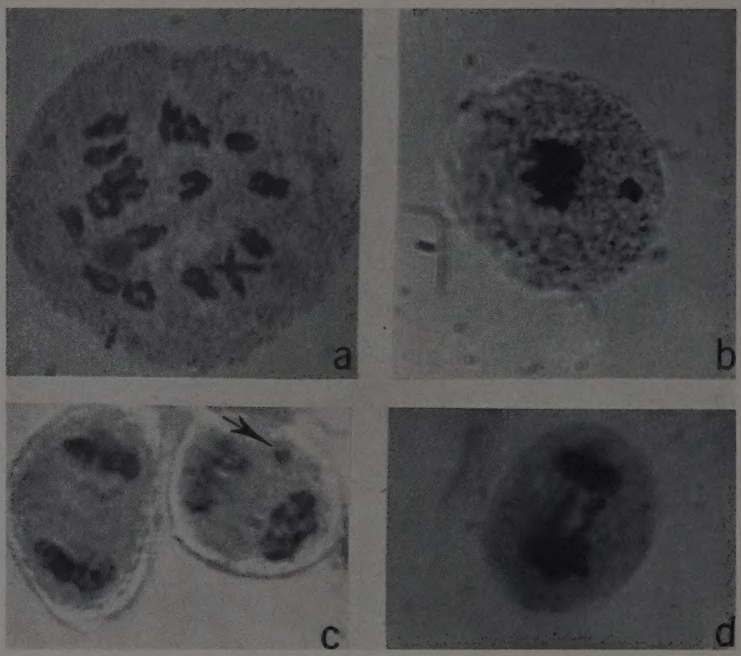
METHODS AND MATERIALS

Transplants of *H. salicifolius*, *H. grosseserratus*, and the new collection of *H.* × *Kellermani* were grown in an experimental garden during 1954. The culture of *H. salicifolius* (115) was grown from seed originally obtained from the Pearce Seed Company. Two cultures of *H. grosseserratus* (10 and 78) were kindly supplied by Dr. C. B. Heiser of Indiana University; they were collected in New York and Illinois, respectively. Specimens of these plants were prepared and placed in the Herbarium of Ohio Wesleyan University.

In the summer of 1955 flower buds were collected from plants in the experimental garden, fixed in Carnoy's solution (3:1) for 12 hours, and then transferred to 70 percent ethyl alcohol. Pollen mother cells were examined using the aceto-carmine smear technique. Chromosome behavior was studied during diakinesis (late prophase I), metaphase I, anaphase I, and telophase II. Photomicrographs were made using a Leitz Makam camera. Estimates of pollen fertility are based on differential staining of microspores with anilin blue in lactophenol. Fertile pollen stains dark blue; non-fertile pollen remains unstained. Approximately 200 grains were examined from each plant.

RESULTS

The data obtained from an examination of meiosis in the putative hybrid and



EXPLANATION OF FIGURES IN PLATE I

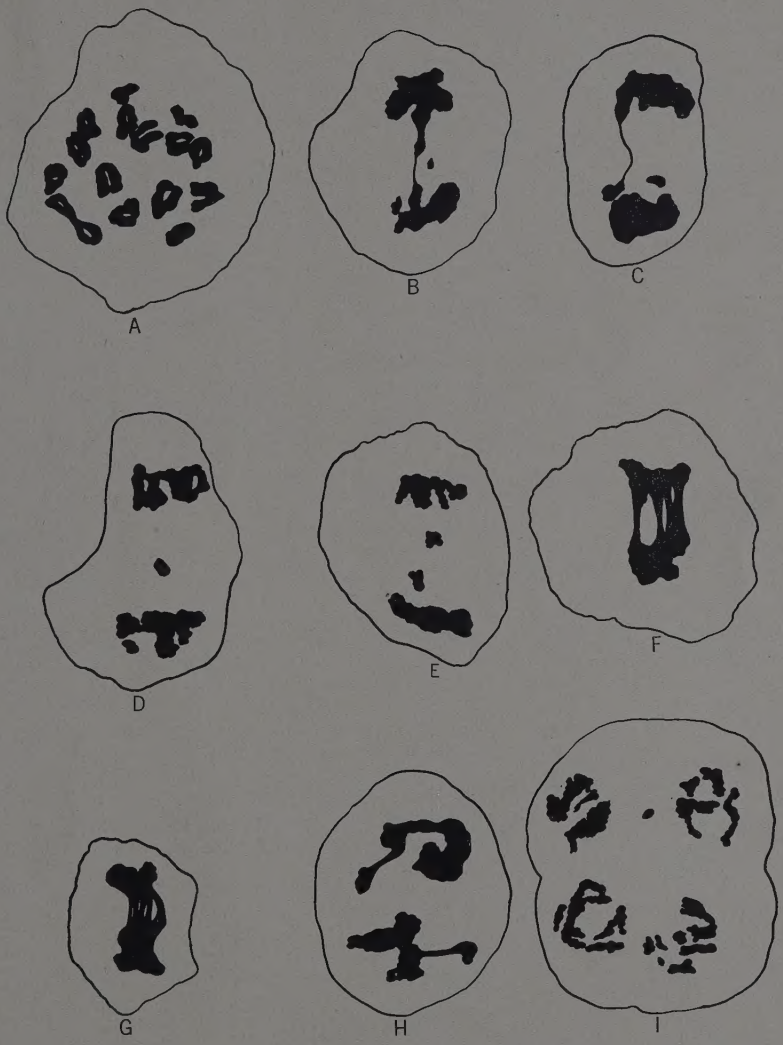
Photomicrographs of representative cells of *H.* × *Kellermani* during microsporogenesis (approximately × 1180).

a. 17 bivalents, normal diakinesis.
b. lagging bivalent, metaphase I.
c. lagging chromosome (arrow), early telophase I.
d. two chromatid bridges (fused chromatids), early telophase I.

EXPLANATION OF FIGURES IN PLATE II

Camera lucida drawings of representative cells during microsporogenesis of *H.* × *Kellermani* (approximately × 1300).

A. 15 bivalents and circle of four chromosomes ("figure eight"), diakinesis.
B. Chromatid bridge and fragment, early telophase I.
C. Chromatid bridge (fused chromatids), early telophase I.
D. Lagging chromosome, early telophase I.
E. Lagging chromosomes, early telophase I.
F. Multiple chromatid bridges, early telophase I.
G. Multiple chromatid bridges, early telophase I.
H. Chromatid bridges (fused chromatids), anaphase II
I. Lagging chromosome, telophase II.



species cultures are presented in table 1. The haploid chromosome number of 17 reported for these sunflowers (Geisler, 1931; Heiser, 1950) is confirmed.

The most common meiotic abnormality in the hybrid was the formation of rings and chains of from 3 to 6 chromosomes during diakinesis (22 percent of cells examined). Usually this was a chain of four chromosomes. Chains were also found in species' cultures, especially in *H. salicifolius* (14.1 percent).

The second most commonly observed abnormality was lagging univalents and bivalents during metaphase (21.5 percent). Laggers occurred in all the other garden plants (Plates I and II).

During anaphase and early telophase I, chromatid bridges with fragments, bridges without fragments ("fused chromatids"), and lagging chromosomes were observed. Several cells contained multiple bridges. All of these aberrations were rare in the other cultures.

Telophase II apparently proceeds normally in the hybrid as well as in the other plants. Regular tetrads are formed almost without exception. No significant number of abnormalities was observed although a few cells contained laggers and micronuclei.

TABLE 1

Meiosis in garden cultures and putative wild hybrid

Plant	Diakinesis				Metaphase I			Anaphase I				Telophase II		
			rings,				with				with			
	no.	17 II	chains	I's	no.	normal	laggers	no.	normal	bridges	laggers	no.	normal	abnormal
grosseserratus														
#78	56	98.2	1.8	0.0	216	97.2	2.8	305	100.0	0.0	0.0	209	98.6	1.4
#10	44	100.0	0.0	0.0	204	92.0	8.0	308	98.4	0.8	0.8	206	99.3	0.7
salicifolius														
#115	52	84.6	14.1	1.3	209	97.4	2.6	313	98.2	0.9	0.9	202	100.0	0.0
× *Kellermani*														
#23	41	75.5	22.0	2.5	212	78.5	21.5	307	90.5	2.4	7.1	208	99.4	0.6

Approximately 12 cells were studied during diakinesis in each plant to obtain chiasma frequencies. It was not possible to study meiosis at earlier stages in this material. The chiasma frequency per chromosome pair in *H. grosseserratus* (78) was $1.41 \pm .01$; in *H. salicifolius* $1.48 \pm .01$; in the hybrid $1.62 \pm .06$. Most of the chiasmata were terminal although X-shaped bivalents were numerous.

The hybrid was vigorous and normal in every external respect during observations that extended over two growing seasons. The morphological intermediacy of the new collection (23) was readily apparent when it was placed along side the putative parental species. Pollen fertility was high in both species cultures and hybrid (90 to 100 percent stainable pollen) although seed-set was poor in open-pollinated heads.

DISCUSSION

In most hybrids between closely related species the chromosomes are either partially or completely paired during prophase and metaphase. Any subsequent lagging, bridge-fragment configurations or other phenomena are associated with lack of chromosome homology. Generally, the chiasma-frequency is somewhat lower than that found in the parental species (Stebbins, 1945). Preliminary counts gave a higher chiasma-frequency in the hybrid than in the putative species. However, the difference for the hybrid is not statistically significant. The putative hybrid exhibited regular chromosome pairing in approximately 75 percent of the cells studied. Lagging was observed during metaphase and early telophase. Bridge-fragments and "fused chromatids" were also formed.

The presence of rings and chains of chromosomes during prophase suggests that chromosomal interchanges have taken place and the two species differ by at least one translocation. It would appear that adjacent chromosomes usually pass to opposite poles since pollen fertility is high.

Lagging bivalents were frequent in the hybrid and were also observed in all parental cultures. Most hybrids between closely related species have normal spindle behavior. Lagging bivalents in these sunflowers may be caused by certain internal factors that upset the spindle mechanism and terminalizations' timing relations (Stebbins, 1945). Certain environmental factors, such as temperature, might also tend to interfere with normal spindle behavior. This lagging did not seem to affect the later course of meiosis, however, at least to any extent.

During anaphase and early telophase chromosome behavior was normal except for an occasional cell with bridge-fragment configurations, "fused chromatids," and laggers. Cross-overs in regions of inversions were assumed to be the cause of bridge-fragments, and probably some of the fused chromatids were formed in the same manner. In addition, fused chromatids may be caused by non-disjunction of one or more pairs of homologues and the persistent association of distal ends of homologous chromatids (Sax, 1932). Restitution nuclei were not seen at telophase I nor were characteristic "dumbbell" shaped nuclei of persistent chromatid bridges observed. The low frequency of bridges and absence of any detectable effect on later stages of meiosis argue against considering them of much importance contributing to genetic isolation. It would appear that inversions, along with translocations, have occurred in *H. salicifolius* and *H. grosseserratus* but that these chromosomal alterations have not been directly important in the evolution of races of the species.

The degree of chromosome homology, vigor, and pollen-fertility in *H.* × *Kellermani* demonstrate that *H. salicifolius* is closely related, cytogenetically, to *H. grosseserratus*. Morphological differences between the two species are quite striking, chiefly because of the unusually narrow leaves of *H. salicifolius*. Both species, however, possess alternate leaves and loose, attenuate phyllaries, and these are probably more important from the taxonomic standpoint. It seems advisable, from the evidence at hand, to include *H. salicifolius* in the "Giganteus" section of the genus (Long, 1954). This will necessitate expansion of the morphological description of the section to include species with disk-corollas red to purplish-brown, as well as those with disk-corollas yellow.

SUMMARY

A cytological analysis of a new collection of *Helianthus* × *Kellermani* has been undertaken to obtain data for evaluating the taxonomic relationship of *H. salicifolius* and *H. grosseserratus*. Approximately 75 percent of the pollen mother cells examined from the hybrid showed regular chromosome-paring. Structural differences were evidenced by the formation of rings and chains of chromosomes and chromatid bridges. Disturbances at metaphase I and anaphase I were also noted, but none of these phenomena interfere with the formation of large amounts and proportions of fertile pollen.

It was concluded that *H. salicifolius* and *H. grosseserratus* are closely related. *Helianthus salicifolius* should be included in the "Giganteus" section of the genus.

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NOTES ON THE GENUS *MACRORHOPTUS* LECONTE
(COLEOPTERA: CURCULIONIDAE, ANTHONOMINAE)
16. A contribution to the knowledge of the Curculionoidea.

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During the past few years a number of the members of the genus *Macrorhoptus* LeConte have been sent to the author in material for identification. Two new forms were found and they are herewith published.

No work has been done on this genus since 1908, when Pierce described *M. sphaeralciae* very briefly. *Macrorhoptus* was described by LeConte in 1876, with *M. estriatus* LeConte the genotype. In 1891, Dietz described an additional species, *M. hispidus*. In 1916, Blatchley and Leng mentioned *M. estriatus* from the area covered by that work.

It is interesting to note that the above named workers, with the exception of Pierce, redescribed the genus in their works noting that the antennal funicle was 6-segmented. However, careful examination shows that the funicle is actually 7-segmented. In all species, with the exception of *sidalceae*, it is clearly evident with careful study. In *M. sidalceae* it is evident on the inner side of the funicle. The seventh segment is very short and wide and might appear, at a glance, to be a segment of the club; but careful examination will disclose that it is actually the last funicular segment.

All measurements of body length were taken from the dorsal view, beginning at the anterior margin of the eyes and extending to the apices of the elytra. Measurements of the rostrum were made from the lateral view along the chord of the dorsal side, from the basal impression or upper margin of the eye to the apical end of the rostrum with the mandibles in a closed position. Those of the pronotum are along the median line. The term pronotum is applied to the disc of the prothorax. In all, 256 individuals have been examined.

Macrorhoptus LeConte

Macrorhoptus LeConte, 1876, p. 208; Dietz, 1891, p. 184; Blatchley and Leng, 1916, p. 284.

Rostrum stout, cylindrical, about as long as prothorax; nearly straight, except at base, and densely scaly. Scrobes oblique, directed beneath the eyes, beginning near apical fourth to two-fifths. Antennae inserted at or near apical fourth to two-fifths. Scape short, stout, gradually widening to apex. Funicle 7-segmented; first funicular segment robust, 2–7 gradually wider, seventh subcontiguous to the club; each segment with whorls of numerous stiff clavate scales. Eyes transversely oval. Head convex, punctured and coarsely pubescent; front with or without a fovea. Prothorax wider than long, narrowed apically; sides nearly straight behind, and frequently rounded in front; apical margin emarginate laterally giving rise to the appearance of feeble postocular lobes. Elytra oblong, very little wider at base than the prothorax; sides nearly parallel, broadly and conjointly rounded at apex, which covers the pygidium completely. Striae almost obsolete; disc of elytra densely punctured, each puncture bearing a scale. Ventral segments rather subequal, third and fourth a little shorter than the others. Legs moderately long; femora feebly clavate, anterior pair armed with a long triangular tooth, middle and posterior pair nearly mutic. Tibiae gradually widened apically; outer angle rounded; anterior feebly curved, middle and posterior pair straight, all armed with a small hook at apex. Tarsi moderately stout, posterior pair more slender, third segment bilobed. Claws armed with a long slender tooth.

In general facies the species resemble in form certain species of *Magdalis*.

Schenkling and Marshall, in the Coleopterorum Catalogus (1934), placed the genus behind *Pseudanthonomus* Dietz, probably on the strength of the original description only, and most likely by virtue of the supposed 6-segmented funicle and the scrobes passing below the eyes.

It would seem that *Macrorhoptus* was more properly placed by Dietz next to *Tachypterellus* in a group made up of *Anthonomopsis*, *Nanops*, *Chelonychus* and the two aforementioned genera, all of which have the middle coxae separated by the mesosternum, posterior tibiae with a small hook and the claws toothed.

Key to the Known Species of MACRORHOPTUS *LeConte*

1. Scaly vestiture on elytra without intermixed erect or semierect clavate bristles..... 2
1'. Scaly vestiture on elytra with intermixed erect or semierect clavate bristles..... 3
2. Scales on rostrum more or less prostrate, broadly oval, those on "ocular lobes" broadly oval; Texas and California..... *estriatus* LeConte
2'. Scales on rostrum erect, elongate and narrowly clavate, those of "ocular lobes" elongate, narrowly clavate; British Columbia..... *sidalceae*, new species
3. Prostrate scales on disc of elytra longitudinally striate, for the most part..... 4
3'. Prostrate scales of disc of elytra not striate at all; smaller and paler species; Texas ..... *sphaeralciae* Pierce
4. Scales of elytra prostrate, having a smoothly, evenly placed appearance; rostrum of female short and stout (fig. 6), aedeagus as in figures 13 and 15; Arizona..*hispidus* Dietz
4'. Scales of elytra very grizzled, being roughened in appearance; rostrum of female elongate and cylindrical (fig. 8); aedeagus as in figures 12 and 14; California..*griseus*, new species

Macrorhoptus estriatus LeConte

Figures 1 and 2

Macrorhoptus estriatus LeConte, 1876, p. 209; Dietz, 1891, p. 185; Blatchley and Leng, 1916, p. 284.

Distribution.—Texas: Halletsville, Victoria (USNM); Goliad, Sonora and Van Horn (ELS). California: Winterhaven. Also recorded from Illinois and Kansas. 151 examples.

This species has been reported to breed in the seed capsules of *Callirrhoe involucrata* by Pierce in Texas.

Macrorhoptus sidalceae, new species

Figures 10 and 11

Male.—Elongate-oblong; black with the antennal funicle, tibiae and tarsi reddish brown; densely clothed with brownish and brownish yellow prostrate, clavate, striate seta-like scales; those of rostrum erect, elongate and narrowly clavate.

Rostrum very feebly curved, a little longer than prothorax, stout, rather finely and very densely punctured, the apical fourth more sparsely punctured and feebly shining. Antennae inserted basad of apical fourth; scape not attaining eye; funicle sparsely clothed with narrow clavate scales; first funicular segment very robust, longer than second, second as long as following two united, three to five subequal, gradually wider, six and seven very short and wide, the seventh contiguous to club. Club short, oval-acuminate and densely clothed with fine setae. Head rather finely and closely punctured. Eyes large and coarsely granulate.

Prothorax more than one-half wider than long, the base one-half wider than apex, apex feebly sinuate at middle, sides feebly arcuate, convergent from base to apex, apex but feebly constricted; pronotum coarsely and densely punctured, each with a narrow clavate scale; flanks more densely punctured. Scutellum rounded.

Elytra one and one-half longer than wide, three times longer and one-third wider than prothorax; humeri rectangular; sides feebly arcuate to apical third then strongly rounded to apex; base bisinuate; striae not impressed, rows of strial punctures indefinable due to the dense, coarse punctures of the intervals; intervals between punctures strongly alutaceous; scaly vestiture prostrate and rather sparse.

Ventral side with pro-, meso-, and metasternum and abdominal sternites coarsely punctured, the punctures a little finer on the abdominal sternites; densely clothed with intermixed clavate and seta-like scales. Fifth abdominal sternite shorter than three and four together, truncated apically, the vestiture finer and a little more erect, first two abdominal sternites feebly impressed

or concave at middle. Legs as in *estriatus*. Claws slender and with a long slender tooth. Length 2.4 mm., width 1.2 mm.

Female.—Rostrum narrower, more slender and thus appearing longer than in male, but scarcely so in relation to the prothorax, a little more sparsely and finely punctured. Otherwise not differing notably from the male. Length 2.5 mm., width 1.5 mm.

Type locality.—Sea Island, Vancouver, British Columbia.

Type material.—Holotype (#86), male, allotype, female, and two paratypes in (ELS); 10 paratypes in the collection of G. Stace Smith, all from the type locality, XI–10–54, C. L. Plummer. Length of paratypes 2.2–2.6 mm., width 1.2–1.5 mm.

The type material was bred from the seeds of *Sidalcea hendersoni*.

This seems to be nearest *M. estriatus* LeConte, but differing from that in the erect, elongate, narrowly clavate scales on the rostrum, the elongate, narrowly clavate scales on the "ocular lobes" and in the shape of the female rostrum.

Macrorhoptus sphaeralciae Pierce

Figures 3 and 4

Macrorhoptus sphaeralciae Pierce, 1908, p. 173.

Distribution.—Known only from Texas: Presidio (USNM, ELS), Devils River (type locality) (USNM); Radford and Barrel Ranch (ELS). All material was collected in April-June. 18 examples.

Reared from the seed capsules of *Sphaeralcia angustifolia* from Devils River.

This is the smallest of our species and is quite distinctive in its paler body coloration, and the pale yellow, non-striate elytral scales.

Macrorhoptus hispidus Dietz

Figures 6, 7, 13 and 15

Macrorhoptus hispidus Dietz, 1891, p. 185.

Distribution.—Arizona: Williams (type locality) (USNM); Constellation, Prescott, Perkinsville and Arlington (ELS). 72 examples.

Macrorhoptus griseus, new species

Figures 8, 9, 12 and 14

Male.—Elongate-oblong, robust, black with mandibles, antennae, tibiae, and tarsi reddish brown; very densely clothed with intermixed tan, brown and white striate scales and brown erect seta-like scales, the head, rostrum and prothorax clothed mostly with brown scales, the prothorax with a wide line of white scales each side of pronotum, elytra clothed with a grizzled

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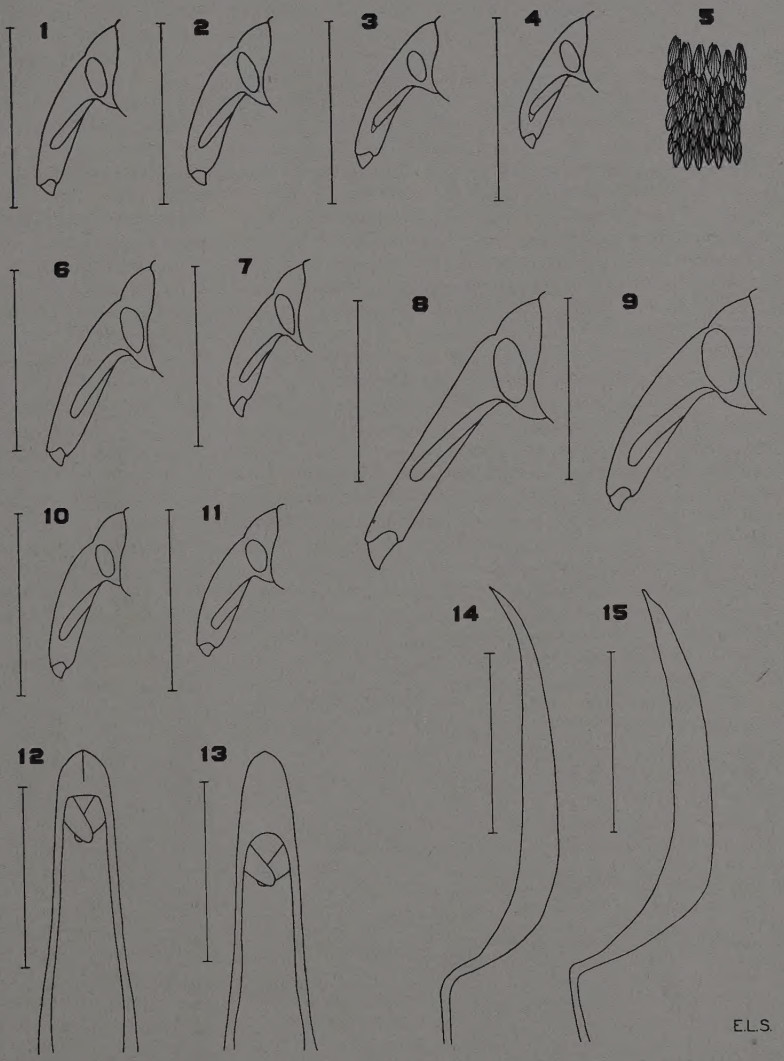
EXPLANATION OF FIGURES IN PLATE

1. Lateral outline of rostrum of *Macrorhoptus estriatus* LeConte, female, Texas.
2. Same of male, Texas.
3. Same of *M. sphaeralciae* Pierce, female, Texas.
4. Same of male, Texas.
5. Illustration of longitudinally striate scales.
6. Lateral outline of rostrum of *M. hispidus* Dietz, female, Williams, Arizona.
7. Same of male, Williams, Arizona.
8. Same of *M. griseus*, n. sp., female, allotype.
9. Same of male, holotype.
10. Same of *M. sidalceae*, n. sp., female, allotype.
11. Same of male, holotype.
12. Dorsal outline of apical area of aedeagus of *M. griseus*, n. sp., holotype.
13. Same of *M. hispidus* Dietz, Williams, Arizona.
14. Lateral outline of major portion of aedeagus of *M. griseus*, n. sp., holotype.
15. Same of *M. hispidus* Dietz, Williams, Arizona.

Figures 1 to 4, 6 to 10.....Line=1 mm.
Figure 5 .....90x
Figures 12 and 14.....Line=½ mm.
Figures 13 and 15.....Line=¼ mm.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mixture of tan, brown and white broad, oval, overlapping scales, the brown seta-like scales in a single row on each elytral interval; abdominal sternites and legs clothed with white scales.

Rostrum as long as prothorax along midline, nearly straight, stout, very closely, coarsely, deeply punctured, except at apex, where the punctures are finer and sparser. Antennae inserted at apical fourth. Scrobes deep, linear, directed beneath the lower angle of the eye. Antennal scape slightly curved, bare, except for an occasional clavate scale; funicle sparsely clothed with erect seta-like scales; first segment robust, about one and one-half times longer than second, nearly as long as next two combined, second nearly twice as long as third, third to fifth subequal gradually wider, sixth and seventh shorter. Club elongate oval, as long as preceding four funicular segments combined; moderately clothed with fine setae. Eyes large, oval, finely granulate. Head rounded, coarsely, deeply, densely punctured, the punctures becoming fine striae on sides of head behind eyes.

Prothorax one and one-third times wider than long, the sides feebly rounded, gradually convergent from base to apex; base twice as wide as apex, base truncated, apex feebly constricted, apical margin strongly bisinuate; pronotum slightly convex, coarsely, densely, deeply punctured, the punctures very narrowly separated; each puncture with either a broad elongate scale or an elongate-narrow scale; flanks more densely punctured. Scutellum rounded, deeply, densely punctured.

Elytra broadly oval, about one and one-half times longer than wide, two and two-thirds times longer than prothorax, one and one-third wider than prothorax; humeri rectangular; sides very feebly arcuate, almost parallel in basal two-thirds, thence strongly rounded to apex; base feebly bisinuate; striae, with the exception of the first, not impressed, the first deeply impressed to beyond middle, rows of strial punctures indefinable due to the dense coarse punctures of the intervals; the intervals between the punctures very feebly alutaceous.

Ventral side with pro-, meso-, and metasternum very coarsely deeply, densely punctured, those of the abdominal sternites smaller and not so well defined, a little sparser; vestiture of intermixed broad oval-elongate scales and prostrate seta-like scales, except along the apical margin of the fifth abdominal sternite which has a denser patch of erect seta-like scales. Fifth abdominal sternites shorter than preceding two combined, apex truncate. First two abdominal sternites feebly concave at middle. Legs as in *hispidus*. Claws with a long slender tooth. Length 3.8 mm., width 1.8 mm.

Female.—Rostrum one-third longer than prothorax, very straight, slender and cylindrical. Apical area anterior to antennal insertion more finely punctured. Antennae inserted at apical third. The first and second abdominal sternites more convex than in the male. Otherwise not differing notably from the male. Length 4.2 mm., width 2.0 mm.

Type locality.—Chocolate Mountains, California.

Type material.—Holotype (#87), male, and allotype, female, in (ELS); one male paratype in the collection of C. A. Frost; all material from the Chocolate Mountains, California, IV–9–39, R. P. Allen. Length of paratype 3.6 mm., width 1.75 mm.

This species differs from *hispidus* by the characters set forth in the key, the grizzled, roughened appearance the longer more cylindrical rostrum of the female and the form of the aedeagus.

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THE HYDROLYSIS OF SUCROSE, LACTOSE, AND CELLOBIOSE BY SMALL INTESTINAL MUCOSA *IN VITRO*.

RELATIONSHIP TO LAXATION IN THE RAT PRODUCED BY THESE DISACCHARIDES *IN VIVO*[1]

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The ingestion of lactose in fairly large amounts is followed by laxation in many species of animals. The available evidence suggests that this laxation occurs because lactose is rather slowly hydrolyzed in the digestive tract; hence, unsplit molecules remain for a rather long time in the lumen and exert a prolonged osmotic (hydragogue) effect. This mechanism is suggested by direct experiments in the dog (Albertoni, 1891; Röhmann and Nagano, 1903), and by indirect evidence in several other species (reviewed by Fischer and Sutton, 1949). To further test the idea that slow hydrolysis rate and laxative action are related in the rat, it seemed desirable to compare the hydrolysis and laxative action of several disaccharides. In addition to lactose, the disaccharides sucrose and cellobiose were chosen for study. Sucrose was chosen because, even at high levels in the diet, it does *not* produce much diarrhea in the rat (Mitchell, 1927). Cellobiose was studied, on the other hand, because the very low "absorption coefficient" of this disaccharide in the rat suggested that the rate of intestinal hydrolysis of cellobiose was slow (Vaniman and Deuel, 1944). Thus, cellobiose in the gut would be expected to produce diarrhea readily.

The present paper gives (a) the relative laxative actions of sucrose, lactose, and cellobiose administered by stomach tube to fasted rats; and (b) the relative rates of the hydrolysis of these three disaccharides catalyzed by rat small intestinal mucosa *in vitro*, and the effects of calcium gluconate and calcium lactate thereupon. Limited data on the activity of certain disaccharidases in calf and pig mucosa also are given.

METHODS

Male rats of a modified Wistar strain were obtained from the colony of the Department of Agricultural Biochemistry of The Ohio State University.

The rats were fed a stock diet containing 60 percent yellow corn meal, 18 percent casein (commercial), 14 percent linseed oil meal, 6 percent alfalfa leaf meal, 1 percent sodium chloride, and 1 percent calcium carbonate, *ad libitum*, plus whole milk *ad libitum*.

When the laxative action of disaccharides was studied, nine mature rats were housed in individual cages with wire screen floors. The rats' feces dropped through the screens onto papers. The papers were changed every day. The rats were fasted for 24 hours, at the end of which time they averaged 282 gm. in weight. Then, 5.0 ml. of a solution containing a known amount of a disaccharide in distilled water was administered by stomach tube. The rats were then allowed the stock diet *ad libitum*, but no milk. On each succeeding day, the feces were examined and the diarrhea classified according to the method of Riggs and Beaty (1947). When no more diarrhea occurred, feed was withdrawn again, and the procedure was repeated with a different disaccharide or a

[1]Supported by a grant from the American Dry Milk Institute, Inc. An abstract of this work has been published (Fischer, J. E., 1955a).

different amount of disaccharide. A number of such trials were conducted with each rat.

Small intestinal mucosa was prepared for use in the *in vitro* studies of disaccharidase action as follows. Calf and pig intestines were obtained as soon as the viscera were removed in the usual slaughter procedure. Sections of intestine were washed out with tap and distilled water. The mucosa was stripped out by hand without slitting the gut open, blended in a Waring blendor, and preserved with toluene in the cold for one or more days. Later, aliquots were ground with sand in a mortar, diluted with approximately ½ volume of distilled water, and stored in the cold until used. For the rat preparations, mucosa was stripped from the entire cleaned small intestine immediately after chloroforming the rats. The mucosa was ground with sand and toluene, diluted (usually), and stored in the cold until used. Exceptions to this procedure were that for one rat preparation (R1) the ground mucosa was used directly without dilution, and for another rat preparation (R2) a turbid, toluene water extract of mucosa was prepared (table 2).

The enzymatic hydrolysis of the disaccharides *in vitro* was studied by a procedure based on that developed by Cajori (1935) for dog mucosal lactase. The digestion mixtures contained 1.0 or 2.0 ml. of mucosa preparation, 2.0 ml. of 0.2 M sodium acetate - acetic acid buffer, and 100 mg. of a disaccharide added either in 2 ml. of a 5 percent or 1.0 ml. of a 10 percent (w/v) solution in distilled water. The final total volume of the reaction mixture was 5.0 ml. The proportion of mucosa preparation, either ⅕ or ⅖, in the total digestion mixture was the same for all experiments with any one preparation. However, there were differences both in the amount of dilution of the original mucosa preparations and in the proportion of mucosa in the digestion mixture with different preparations, so that the results with different preparations are not directly comparable one with another. The buffer was at pH 5.6 in the rat and pig experiments, and at pH 5.4 in the calf experiments, except where otherwise noted in table 2. The enzymatic reaction was started by mixing the substrate solution with the other components at 39.5° C. The mixtures were incubated at 39.5° C for the lengths of time given in table 2. Aliquots of the digestion mixture after incubation were clarified according to Cajori (1935). The total monosaccharides liberated in the enzymatic hydrolysis were estimated in the clarified filtrate by a slight modification of the Tauber-Kleiner (1932) method, and the percentage hydrolysis of the disaccharide substrate was calculated. Control digestion mixtures were prepared and incubated using boiled mucosa, and treated as given above. These boiled controls never gave any appreciable reduction of the acid-copper reagent of Tauber and Kleiner (1932), indicating that the hydrolysis observed with the fresh mucosa preparations was entirely enzymatic.

RESULTS

The effects of disaccharides upon laxation are given in table 1. Up to 2.5 gm. of sucrose administered by stomach tube under the conditions described had no laxative effect in the rat in any of the trials. Lactose first initiated laxation at the level of 1.2 gm. per dose. Cellobiose first initiated laxation sometimes at the level of 0.5 gm., and always at the level of 0.8 gm.

Table 2 gives the results of the enzyme studies. It shows that rat, calf, and pig mucosa catalyzed the hydrolysis of both lactose and cellobiose. In all three species, the amount of lactose split was double or more the amount of cellobiose split in the same length of time. The differences between lactase and cellobiase in the rat and in the calf were not due to hydrogen ion effects since all of the determinations were conducted at the optimum pH for the enzyme activities. The pH optima for activity were determined in preliminary experiments to be as

TABLE 1

Laxative action of disaccharides administered by stomach tube to fasted rats

Sugar	Amount given (gm. sugar/5.0 ml. of solution)	No. of trials	Laxation
Sucrose	0.5	6	None
	2.5	5	None
Lactose*	0.5	6	None
	0.8	5	None
	1.2	5	Slight to moderate
	1.5	5	Slight to moderate
	2.0	2	Moderate to severe
	2.5	5	Moderate to severe
Cellobiose†	0.5	5	None to moderate
	0.8	5	Slight to severe

*Eastman, 98% β, form initially dissolved at room temperature just before administration.
†Eastman; the cellobiose solutions were heated to aid solution, then cooled and made to volume.

TABLE 2

Relative rates of hydrolysis of three disaccharides by small intestinal mucosa in vitro, *and effects of calcium gluconate and calcium lactate thereupon*

Mucosa source*	Mucosa preparation		Incubation time (hours)	Substrate	% hydrolysis		
	No.	Nature			Alone	With calcium salts† Gluconate	Lactate
Rat	R1	Ground	3	Lactose	23.7	8.3	25.8
Rat	R2	Ground, diluted, centrifuged; turbid supernate used	22½	Cellobiose	12.6	7.3	
			3	Lactose	27.4	9.5	
			3¾	Sucrose	47.0	48.5	
Rat	R3	Ground, diluted	21½	Cellobiose	28.3	26.6	
			5	Cellobiose	11.8	10.0	
			2	Cellobiose	9.1		
			2	Lactose	16.6		
			2	Sucrose	43.5		
Rat	R5	Ground, diluted	2	Cellobiose	7.7	6.7	
			2	Lactose	19.8	10.0	19.5
Rat	R6	Ground, diluted	2	Lactose	19.0	10.7	
			2	Sucrose	65.8	64.7	
Pig	P1	Ground, diluted	2½	Cellobiose	6.8		
			2½	Lactose	17.6	9.9	
			4	Cellobiose	9.8	7.4	
			4	Lactose	24.7		
Calf	C1	Ground, diluted	2½	Lactose	45.1		
			2⅔	Cellobiose	12.0		
			16⅓	Cellobiose	31.0		
			16⅓	Sucrose‡	0.0		
			28¼	Sucrose§	0.0		

*Each of the rat preparations contained pooled mucosa from three or more rats. The pig preparation was obtained from one pig of unknown sex, age, or weight. The calf mucosa was obtained from an Ayrshire bull calf which weighed 395 lbs.
†1% or 2% (w/v) in the reaction mixture; when both levels of salts were tested, the results were close and were averaged.
‡This test was made at both pH 6.0 and 6.8.
§This test was made at pH 6.0.

follows: rat lactase, 5.6; rat cellobiase, 5.0 to 5.6; calf lactase, 5.4 to 5.6; calf cellobiase 5.0 to 6.0; pig lactase, 5.6 (The optimum pH for pig cellobiase activity was not determined).

Table 2 shows also that sucrose hydrolysis by rat mucosa is about 2 to 3 times as great as lactose hydrolysis in the same length of time under our conditions at pH 5.6. The optimum pH for rat sucrase activity was not determined; however, if the optimum for the sucrase is somewhat different from pH 5.6 this would merely increase the difference between sucrase and lactase activity *in vitro*, and would not alter the fact that sucrase is considerably more active than lactase in the rat. Detailed studies of the kinetics of the hydrolysis of the different disaccharides were not carried out with the crude mucosa preparations. Therefore, for the present, the relative hydrolysis rates must be regarded only as approximate estimates of the relative orders of magnitude of the three enzyme activities *in vitro*.

Sucrose was not hydrolyzed at all by calf mucosa under our conditions (table 2). This confirms the early work of Fischer and Niebel (1896).

Table 2 shows also that the presence of calcium gluconate in the reaction mixtures markedly inhibited, but did not completely abolish, lactose hydrolysis by rat (and also, pig) mucosa. Calcium lactate had no significant effect upon rat lactase. This indicates that the inhibition by calcium gluconate was due to gluconate ions rather than to calcium ions. Calcium gluconate inhibited rat and pig cellobiase also, but the degree of inhibition was rather slight in most of the trials. Calcium gluconate did not inhibit rat sucrase.

DISCUSSION

Several observations reported herein are consistent with previous evidence that slow intestinal hydrolysis is a primary factor in the laxation which results from the ingestion of certain disaccharides. First, we have shown herein that the relative activities of three disaccharidases in rat small intestinal mucosa *in vitro* are cellobiase $<$ lactase $<$ sucrase, while the relative laxative potencies of the corresponding disaccharides tested in the rat are cellobiose $>$ lactose, with no laxation due to sucrose under our conditions. The relative cellobiase and lactase activities agree well with the relative rates of disappearance from the rat gut of cellobiose (Vaniman and Deuel, 1944) and lactose (Cori and Cori, 1928; Coryell and Christman, 1943; Fischer and Sutton, 1953). Second, we have shown that gluconate inhibits mucosal lactase *in vitro*. This is consistent with the finding of Mitchell *et al.* (1939) that gluconate in the diet markedly intensified the diarrhea produced by feeding lactose to rats. These workers showed that the effect of gluconate was not exerted with glucose, galactose, sucrose, starch, or dextrin in the diet. Thus, our finding that gluconate had no effect upon rat sucrase *in vitro* also is completely consistent with the *in vivo* experiments of Mitchell *et al.* (1939). The present experiments, considered together with the previous evidence (Fischer and Sutton, 1949; Bailey *et al.*, 1956), leave no doubt that hydrolysis rate is an important factor in the laxation produced by disaccharides.

On the other hand, the rate of intestinal absorption of the monosaccharide end products of disaccharide hydrolysis does *not* appear to be an important factor contributing to the laxation produced by cellobiose or lactose in the rat. This is because glucose, galactose, or a mixture of the two monosaccharides is absorbed from the gut generally faster than cellobiose or lactose is hydrolyzed (Cori, 1925; Cori and Cori, 1928; Coryell and Christman, 1943). Therefore, large numbers of monosaccharide molecules do not accumulate in the gut lumen during the absorption of lactose (Coryell and Christman, 1943) or cellobiose (Vaniman and Deuel, 1944), so a deleteriously high osmotic (hydragogic) action cannot be due to the monosaccharide products.

The finding in rat, pig, and calf small intestinal mucosa of an enzyme which catalyzes cellobiose hydrolysis confirms the original report of the existence of such an enzyme in animals (Porcher, 1910). (In Porcher's work it was not entirely clear what animals were tested for cellobiase; in other experiments reported in the same paper donkeys and dogs were used.) Oppenheimer (1925) stated that the cellobiase action observed by Porcher was due to microorganisms. In our work the intestines were washed out thoroughly and toluene was always present during storage and incubation of the mucosa preparations so that the hydrolysis of cellobiose almost certainly was due to an animal enzyme rather than to microbial action. The presence in intestinal mucosa of an enzyme which catalyzes the hydrolysis of various aryl-β-D-glucosides has been reported (Thomas and Frouin, 1909; Steensholt and Veibel, 1943); it is not known whether the hydrolysis of these compounds is due to the same enzyme as is the hydrolysis of cellobiose reported herein. The presence of cellobiase in rat mucosa explains the physiological evidence (intestinal absorption, glycogen formation, and ketolytic action) which indicates that the normal rat can utilize cellobiose to some extent (Vaniman and Deuel, 1944). The fact that cellobiose had a ketolytic action *in vivo* equivalent to that of glucose (Vaniman and Deuel, 1944) indicates that the cellobiose disappearance from the gut *in vivo* probably was not due to microorganisms since the microbial production of non-ketolytic fermentation products would have made cellobiose a less active ketolytic agent than glucose. Thus, enzymatic and physiological evidence establish the presence of cellobiase in the rat, and enzymatic evidence establishes the presence of this enzyme in the calf and pig.

Several observations indicate that marked differences exist among mammals in the ability to hydrolyze different disaccharides. First, the occurrence and the relative activity of the various disaccharidases vary in different species (this paper; Fischer and Niebel, 1896). Second, there may be differences between species in the time of first appearance of the different disaccharidases; these enzymes may appear first in embryonic life (Needham, 1931; Heilskov, 1951) or in early postnatal life (Bailey *et al.*, 1956). Third, the persistence of each disaccharidase and the changes in its activity at different ages of life may vary in different species (Plimmer, 1906; Heilskov, 1951; Bailey *et al.*, 1956). Fourth, the total activities in the small intestinal mucosa (of the rat, at least) may be affected by prolonged feeding of a disaccharide (lactose) (Fischer, 1955b, 1956). Fifth, other constituents of the diet may affect the hydrolyses directly (as has been shown herein with calcium gluconate) or indirectly (Fischer and Sutton, 1949). All of these observations suggest that suitable levels of intake of a particular disaccharide must be determined separately for each species, for each stage of development, and for each dietary regimen.

SUMMARY

The relative laxative actions of three disaccharides administered by stomach tube to fasted rats was cellobiose > lactose, and no laxation with sucrose under our conditions. The relative disaccharidase activity of rat small intestinal mucosa *in vitro* was sucrase > lactase > cellobiase. Calcium gluconate, but not calcium lactate, inhibited lactase strongly (but not completely under our conditions). Gluconate inhibited cellobiase slightly, but did not inhibit sucrase. These results, in conjunction with information from other experiments, establish that slow hydrolysis of disaccharides is responsible for the induction of the laxation which follows the ingestion of certain disaccharides by the rat.

Cellobiase activity was detected in the small intestinal mucosa of a calf and a pig. In the mucosa of both species, as in the rat, the hydrolysis of cellobiose *in vitro* was slower than that of lactose. In pig mucosa, as in the rat, gluconate inhibited lactase strongly and cellobiase slightly.

The absence from bovine small intestinal mucosa of sucrase was confirmed.

ACKNOWLEDGMENTS

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PLEISTOCENE MOLLUSCAN FAUNULES OF THE SIDNEY CUT, SHELBY COUNTY, OHIO

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INTRODUCTION

The Sidney cut, from which the fossil mollusks were obtained, lies two miles south of Sidney along the Baltimore and Ohio Railroad (fig. 1). The section is present in steep cuts on both sides of the tracks, but the mollusk-bearing strata are exposed only at one spot near the base of the east cut. This is the same section from which has been recovered Pleistocene wood, present on top of a rather well-developed soil formed in till. The wood is dated at 23,000±800 years (W-188, Rubin and Suess, 1955, p. 483). This section plays an important role in the conclusions of a paper by Flint and Rubin (1955, p. 651), in which they suggest a simpler, twofold division of the Wisconsin stage.

The mollusk-bearing strata lie at the base of the section (fig. 2), below the wood and the till which contains the buried soil. Because the buried soil appears quite well developed, it has been called late Sangamon by some geologists and soils scientists. Should this soil be so interpreted, deposits of "Early" Wisconsin time[1] must be entirely lacking. The stratigraphic position of this soil is very like that of other buried soils developed in gravel at a large number of widely scattered locations in west-central Ohio. These soils appear to show less development than the soil in the Sidney cut and are interpreted as mid-Wisconsin by Goldthwait (1955, p. 41) on the basis of their similarity to modern gravel soils. The stratigraphic position of the buried soil in the Sidney cut suggests that it also might be mid-Wisconsin.

The age of the soil, then, is not clear. Since this soil and this section are a focus for arguments regarding the nature of the subdivision of the Wisconsin, it is essential to consider any new evidence concerning the age of the soil. Discovery of mollusks from a silt below the thick till in which the soil is developed could provide a clue.

Radiocarbon dates from a stream cut on upper Brush Creek, two miles southeast of the Sidney cut, have recently been received. This section is about 15 feet thick and contains two tills separated by an intervening nonglacial deposit, all overlain by post-glacial alluvial gravel. The intervening deposit is noncalcareous and consists of poorly-sorted and partly-rotted gravel overlain by mottled blue and brown clay, with a thin discontinuous peaty zone at the upper contact. Wood from near the base of the upper till is dated at 22,000±1,000 years (W-414) whereas a sample from the underlying peaty zone is dated at more than 37,000 years (W-415, M. Rubin, personal communication, May 18, 1956). The significance of these dates will be discussed in a later section where all implications concerning the glacial history will be considered.

[1]The terms "Early" Wisconsin and "Late" Wisconsin, as used in this paper, follow the usage of R. P. Goldthwait (1952, 1955). Basic Wisconsin stratigraphy in Ohio appears to be a lower till, overlain by gravel, which is in turn covered by a surface till. A buried soil, developed at the top of the gravel, marks an ice-free period of sufficient duration for soil formation. Materials pre-dating the soil are called Early Wisconsin; those post-dating the soil are called Late Wisconsin. In this paper the term "mid-Wisconsin" is used to refer to the period of soil formation.

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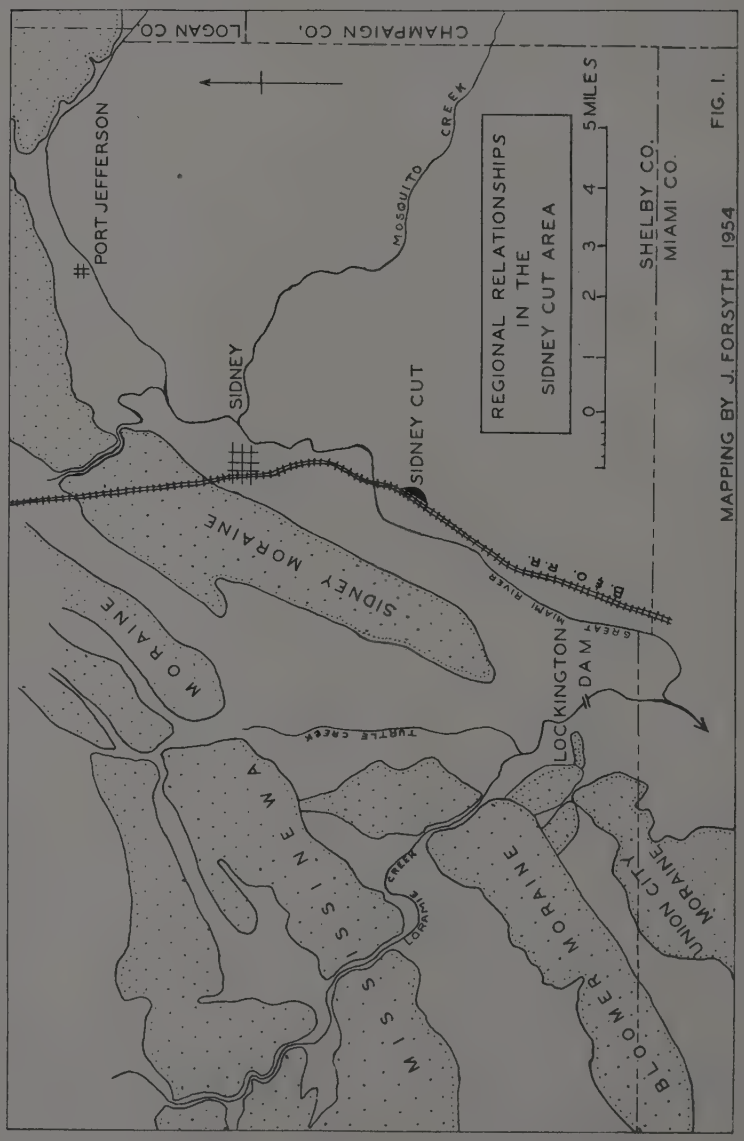
LOGAN CO.
CHAMPAIGN CO.
PORT JEFFERSON
MOSQUITO CREEK
SIDNEY
SIDNEY CUT
REGIONAL RELATIONSHIPS
IN THE
SIDNEY CUT AREA
0 1 2 3 4 5 MILES
SHELBY CO.
MIAMI CO.
MAPPING BY J. FORSYTH 1954
FIG. 1.
B & O R.R.
GREAT MIAMI RIVER
SIDNEY MORAINE
MORAINE
TURTLE CREEK
LOCKINGTON DAM
MISSISSINEWA
LOST CREEK
BLOOMER MORAINE
UNION CITY MORAINE

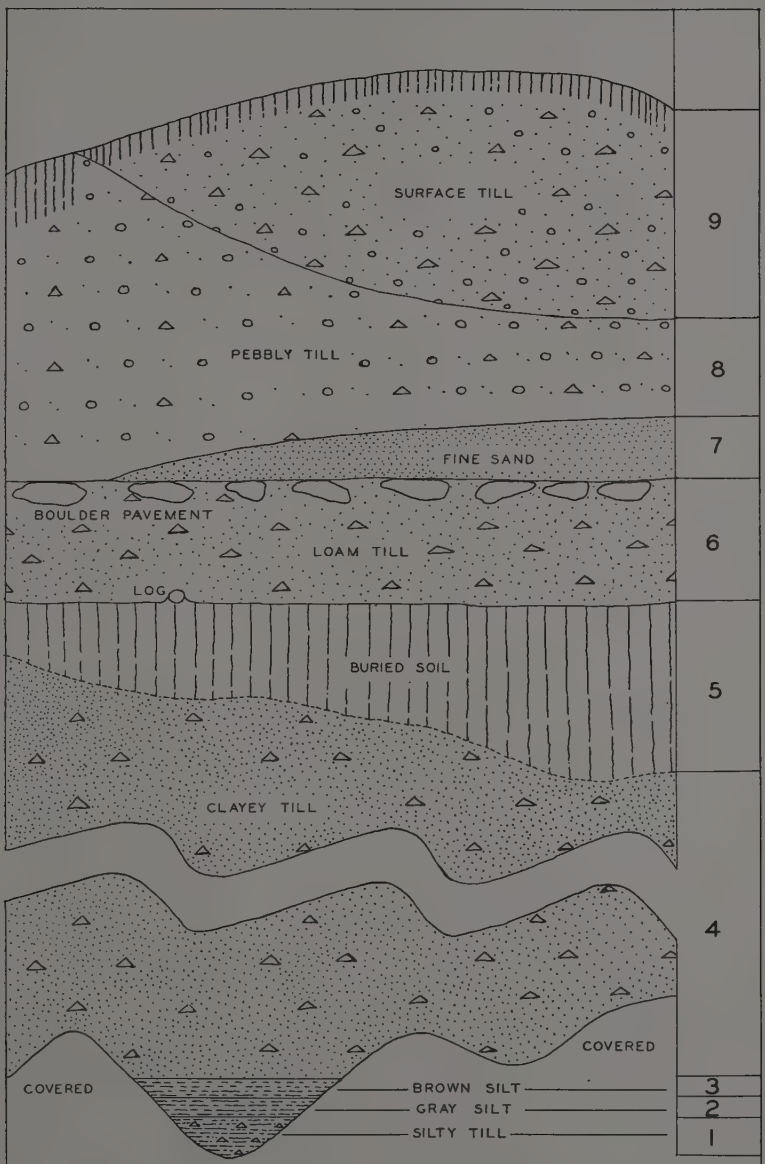

FIG. 2. STRATIGRAPHIC SECTION AT SIDNEY CUT

STRATIGRAPHY

Five tills are present in the Sidney cut. The tills vary somewhat in mechanical composition, but not enough to be identified in occurrence elsewhere; the differences are best observed in the face of the cut. Evidence for repeated disappearance of ice from this spot lies at the top of each of four of these tills. The type of evidence varies, being the presence of a soil above the first (top) and fourth tills, the presence of a boulder pavement and sand above the third, and the presence of fossiliferous silts above the fifth (lowest). The section is as follows:

Unit	*Description*	*Thickness (feet)*
9	Till, reddish-brown, with clayey loam texture, with small silt or sand lenses, discontinuous surface distribution, soil profile leached 24 to 27 inches	0–7+
8	Till, brown, loam texture, very pebbly; soil profile is leached 43 or so inches where it reaches the surface	5±
7	Sand, fine, well sorted and bedded	0–2
6	Till, reddish-brown above unoxidized gray till; loam texture. Embedded in top of till is a boulder pavement, without striae on boulders, developing along a remarkably straight and horizontal line	4±
5	Buried soil, bright limonitic red at top, less red toward base, leached to a maximum of 4 feet, with dolomite pebble ghosts near bottom. Log was lying on this soil and incorporated soil material in the wood	0–6
4	Till, gray-blue, clayey loam texture	30±
3	Silt, brown, fossiliferous	½
2	Silt, gray, fossiliferous, seeming to grade into underlying till	½
1	Till, gray, silty loam texture, somewhat pebbly	1+
	Base covered	

REGIONAL RELATIONSHIPS

The Sidney cut occurs on the till plain outside (south of) the sequence of Late Wisconsin moraines present in western Ohio. Just to the northwest lies the Sidney moraine, so named because it underlies part of the town of Sidney.

Leverett (1902, p. 476) correlated this moraine with the Union City moraine from the west, but recent work in Shelby County (Forsyth, 1956) shows that the Union City moraine turns north, west of Lockington Dam, and is overridden by a younger moraine, the Bloomer moraine (named for a town on its crest in Miami County). This interpretation is based on the topographic pattern at the place of junction. The Union City moraine here has a northwestward trend and is not very high, becoming lower toward the north; the Bloomer moraine trends northeast-southwest, almost at right angles to the Union City moraine, and is markedly higher. To the north, the Mississinewa moraine overrides the Bloomer in the same fashion; here the relationships are even clearer and more striking.

The Sidney moraine appears to be older than any of the moraines discussed above. It may be traced westward across Turtle Creek to the area of junction of the Bloomer and Union City moraines west of Lockington Dam, where it appears to pass under the Bloomer moraine. The relationship of the Sidney and Union City moraines is not clear, but the former seems to pass under the Union City moraine also. This interpretation would make the Sidney moraine the oldest of all these Late Wisconsin recessional moraines in Shelby County. The Sidney cut lies to the south of this moraine, and is therefore even older.

COMPOSITION OF THE MOLLUSCAN FAUNULES

The material collected consists of Mollusca obtained by sieving from two large samples from units 2 and 3 of the section. The sample from unit 2 yielded 238 specimens, that from unit 3, 286 specimens. The relative numbers of the species are shown in table 1.

NATURE OF THE ENVIRONMENT

The genera represented, with the exception of *Fossaria*, are land pulmonate gastropods. *Fossaria parva* will live in very small, even temporary, bodies of water and its presence in unit 2 indicates nothing more than the existence of puddles or pools of water at the time when these snails were alive.

TABLE 1

Composition of the molluscan faunules from units 2 and 3 of the Sidney Cut, Shelby County, Ohio

Species	Unit 2		Unit 3		Ohio
	Number	Percent	Number	Percent	Now
Carychium exile canadense Clapp	27	11.4	11	3.8	No
Cionella lubrica (Müller)	1	0.3	1	0.4	Yes
Columella alticola (Ingersoll)	0	——	11	3.8	No
Deroceras? sp.	0	——	1	0.4	?*
Discus cronkhitei (Newcomb)	0	——	1	0.4	Yes
Euconulus? sp.	1	0.3	0	——	?*
Fossaria parva (Lea)	8	3.4	0	——	Yes
Hawaiia minuscula (Binney)	0	——	4	1.4	Yes
Helicodiscus sp.	2	0.8	0	——	?*
Helicoid, undetermined fragments	4	1.7	0	——	?*
Stenotrema sp.	9	3.8	8	2.8	?*
Succinea avara Say	39	16.4	59	20.6	Yes
Succinea grosvenori Lea	76	32.0	24	8.4	No
Vallonia gracilicosta Reinhardt	9	3.8	76	26.5	No
Vertigo alpestris oughtoni Pilsbry	62	26.1	90	31.5	No

*These specimens could not be identified to species, in one case not even to genus, because of their fragmentary condition. It is probable that the species represented occur in Ohio but they must be recorded as doubtful in the absence of specific identification.

An uneven land surface such as might be developed on the surface of a ground moraine would have hollows in which *Fossaria parva* could establish itself and survive. This sort of environment would also be suitable for *Succinea grosvenori*. Along the margins of the pool, *Carychium*, *Cionella*, and *Helicodiscus* would find a congenial habitat. On the higher, somewhat drier ground, *Euconulus*, *Stenotrema*, *Succinea avara*, *Vallonia*, and *Vertigo* would thrive, especially if vegetation covered the ground. There is no indication here of a forest cover or even light woods. A thick growth of bushy plants, such as alders, would be ideal. *Vallonia*, in fact, thrives with no more cover than a thick growth of grass and shrubs.

As the snails died, their shells would be washed into the hollows, along with silt and dead leaves. In the situation presented by units 2 and 3 of this section, this could be accomplished by the flow of rain down the gentle slopes to the hollows. Eolian transportation could be a factor in the transfer of fine material from the higher ground to the hollows but there is nothing to indicate that it played a major role.

The filling in of the pool and the general leveling of the surrounding surface may account for the disappearance in unit 3 of *Fossaria parva* and for the dwindling numbers of *Carychium exile canadense* and *Succinea grosvenori* and the corresponding

increase in numbers of *Succinea avara*, *Vallonia gracilicosta*, and *Vertigo alpestris oughtoni*. It may also account for the appearance in unit 3 of *Columella alticola*, *Discus cronkhitei*, and *Hawaiia minuscula*, although these may have been washed in from higher ground.

It is emphasized that the ecology of the fauna does not demand the presence of woods or forest. The nature of the section shows that the ice was not far away and that it overswept the area so soon afterwards that a forest cover may not have developed. Likewise, the habitat preferences of the Mollusca are such that they could easily have existed with a minimum of bush-like plants to provide what little shade they needed.

The presence of ice a short distance away does not seem to have affected the development of a land snail population to any great extent. The two assemblages described could be duplicated at the present time in the southern parts of eastern Canada, as far west as Manitoba.

TABLE 2

Stratigraphic range of identified species of the Sidney Cut faunules

Species	PLIO	NE	AF	KA	YA	IL	SA	WIS
Carychium exile canadense Clapp	O	O	O	X[a]	X[f]	X[f]	X[f]	X[e]
Cionella lubrica (Müller)	O	O	O	X[a]	X[e]	X[e]	X[e]	X[e]
Columella alticola (Ingersoll)	O	O	O	O	O	O	O	X[e]
Discus cronkhitei (Newcomb)	O	O	O	X[d]	X[e]	X[e]	X[e]	X[e]
Fossaria parva (Lea)	O	O	X[e]	X[a]	X[e]	X[e]	X[e]	X[e]
Hawaiia minuscula (Binney)	X[e]	X[e]	X[e]	X[d]	X[e]	X[e]	X[e]	X[e]
Succinea avara Say	O	O	O	X[a]	X[e]	X[e]	X[e]	X[b e]
Succinea grosvenori Lea	O	O	X[e]	X[a]	X[e]	X[d]	X[e]	X[e]
Vallonia gracilicosta Reinhardt	O	O	X[e]	X[d]	X[e]	X[e]	X[e]	X[d]
Vertigo alpestris oughtoni Pilsbry	O	O	O	X[g]	X[f]	X[f]	X[e]	X[b e]

Explanation of Symbols

PLIO Pliocene
NE Nebraskan
AF Aftonian
KA Kansan
YA Yarmouth
IL Illinoian
SA Sangamon
WIS Wisconsin
[a] Indiana, pro-Kansan (Wayne, 1954)
[b] Indiana (Wayne and Thornbury, 1955, p. 26).
[e] Ohio (Leonard, 1953, p. 372).
[d] Kansas (Frye and Leonard, 1954, p. 45).
[e] Kansas (Leonard, 1950).
[f] By inference, from the existence of a Kansan record.
[g] Indiana, pro-Kansan (Wayne, personal communication).
O Absent.
X Present.

It should be noted also that there is no indication here of the nearness of a stream or of a body of water such as a lake or even a large pond. Stream valleys to the east, south, or west may have accelerated the dispersal of these snails to the Sidney area, but once in the general region, they were able to spread out and occupy the rather wet environment of the uneven moraine surface.

AGE OF THE SIDNEY CUT FAUNULES

In Ohio, age determinations on the basis of molluscan faunules must be made with extreme caution and on a conditional basis for three reasons. In the first place, few assemblages have been studied in sufficient detail to serve for comparison with newly discovered faunules. Secondly, certain species, hitherto considered characteristic of a particular part of the Pleistocene, have later been recorded for younger or older sediments, which has led to modification of ideas on their strati-

graphic significance. Thirdly, species of proven stratigraphic significance in other states, for example in Kansas, where so much has been accomplished by Leonard, may have a different value in Ohio because of different factors influencing the dispersal of Mollusca.

Under these circumstances, all that can be done with these collections from the standpoint of age determination is to assemble all available information on the geologic range of the species in Ohio and elsewhere and to draw provisional conclusions on the basis of these data. In spite of these limitations and uncertainties, a fairly definite conclusion can be obtained concerning the age of the Sidney Cut faunules.

The stratigraphic range of the identified species and forms, so far as known at present, is shown in table 2. The two collections are not separated in this table; they are so close stratigraphically and lithologically that no good purpose would be served by considering them separately. Identifications to genus only have not been included in the list; data from these determinations are too general to have any significance.

The two collections contain five species that are not now living in Ohio. Four of these, *Succinea grosvenori*, *Vertigo alpestris oughtoni*, *Vallonia gracilicosta*, and *Columella alticola*, are entirely absent from the living molluscan fauna of Ohio. The other is represented in Ohio by the typical form but its variety or subspecies, *Carychium exile canadense*, has not been found living in the state. Such a high proportion of locally extinct species (50 percent of forms identified to species) has been considered significant in Ohio and elsewhere and indicates at least Wisconsin age.

An age determination older than Kansan for this deposit seems to be out of the question. Six of the Sidney Cut species have not been recorded for Aftonian deposits and nine of them do not appear in Nebraskan lists.

The position of the deposit under several tills suggests the possibility of a Sangamon, Illinoian, or Kansan age. Of the ten species of the Sidney Cut list, only one, *Columella alticola*, has not been recorded for Sangamon deposits. Only two, *C. alticola* and *Vertigo alpestris oughtoni*, have not been recorded for Illinoian, Yarmouth, and Kansan deposits, but it must be pointed out, in fairness to those who incline to an Illinoian age for the Sidney Cut deposit, that *V. alpestris oughtoni* has been collected by Wayne (personal communication) from pro-Kansan deposits in Indiana. The objection to a Sangamon, Illinoian, or Kansan age rests, therefore, on the occurrence of *C. alticola* in the Sidney Cut deposit and its absence from older Pleistocene deposits.

On the other hand, all the species of the Sidney Cut faunule, including *Columella alticola*, have been recorded from Wisconsin deposits, seven of them by Leonard (1953) from the Wisconsin of the Cleveland region in Ohio.

Advocating an Illinoian age for the Sidney Cut faunule might present a dilemma familiar to all stratigraphic paleontologists: to rely on evidence provided by fossils or to rely on an interpretation based on geological relationships. In this particular case, in order to interpret the Sidney Cut faunule as older than Wisconsin, it must be assumed that *C. alticola* occurs in Pleistocene deposits older than Wisconsin. The assumption is not an impossible one, since the range of other species has been extended in the past. Nevertheless, the fact remains that, so far, *C. alticola* has not been found in deposits older than Wisconsin in Kansas, Illinois, Indiana, or Ohio. In addition, geological evidence favors a Wisconsin age somewhat more strongly than an Illinoian one. Under these circumstances, the dilemma does not appear to exist and we conclude, therefore, that the Sidney Cut faunule must be considered of Wisconsin age unless and until new data indicate otherwise.

The large proportion of extinct species already mentioned leads us to prefer

an Early rather than a Late Wisconsin age but this is only a preference insofar as the Mollusca indicate. It seems to be a logical one, nevertheless, considering the stratigraphic position of the deposit under several tills. It seems to us that, if the Sidney Cut faunule is considered to be Wisconsin in age, it must be placed near the beginning of Wisconsin time in Ohio.

GEOLOGIC IMPLICATIONS OF AGE OF FAUNULE

Data concerning the age of the buried soil in the Sidney cut, and therefore the glacial history of west-central Ohio, are drawn from regional stratigraphy, the radiocarbon datings, the character and development of the buried soil, and the mollusk study just discussed.

The till lying above the buried soil in the Sidney cut is definitely Late Wisconsin, for the radiocarbon date of 23,000 ± 800 years on the log (and also of 22,000 ± 1,000 years on the log from the younger till at upper Brush Creek) is consistent with the pattern of Late Wisconsin datings throughout Ohio (Flint, 1955; Flint and Rubin, 1955; Rubin and Suess, 1956).

The soil lying just below the Late Wisconsin log has been interpreted by some as Sangamon because it appears so well developed. If this should be so, the Early Wisconsin ice would have had to come and go without leaving a trace. Though such a history is not impossible, it seems unlikely. Buried soils developed in gravel are present in many other localities throughout west-central Ohio; a typical example occurs only four miles north of the Sidney cut. These soils are of mid-Wisconsin age. Postulating two distinct stages of soil formation, rather than one, avoids the simplest interpretation and demands substantiation by adequate supporting data. Tests run in the Soils Testing Laboratory (Agronomy Department, The Ohio State University) on the chemical and mechanical composition of the buried soil seem to show a soil development no greater than in a similar modern soil; this is not the intensity of development that would be expected in a soil formed during Sangamon time.

A thick till separates the buried soil from the silts in which the mollusks were found. It has been suggested above that the age of the mollusks is most likely Early Wisconsin, less likely Sangamon, or very unlikely Illinoian. If the most likely age assignment is accepted, that of Early Wisconsin, it follows that the buried soil must be mid-Wisconsin. Even if the less likely Sangamon age for the faunule is adopted, the thick till separating the fossiliferous silts from the buried soil demands the presence of ice, which would have to be of Early Wisconsin age; so again one is led to a mid-Wisconsin date for the buried soil. Since the silts are thin and grade downward into the underlying till, the interval represented by the silts is probably not great; it is not likely to mark an interstadial deposit. If the buried soil is called Sangamon, which has been seriously questioned above, the fossils would have to be of Illinoian age; this has been shown to be very unlikely. This fauna is therefore called Early Wisconsin, and the buried soil above it is assigned to the mid-Wisconsin substage, thus correlating it with the numerous other examples of mid-Wisconsin buried soils in west-central Ohio.

The implications of the older radiocarbon dating on peat beneath the younger till at upper Brush Creek must also be considered. The age determination of this peat as greater than 37,000 years is similar in value to several other determinations from Ohio. The geologic age implied was not known except that it was pre-Late Wisconsin. Correlation of the upper Brush Creek section with the Sidney cut suggests that the upper Brush Creek peat is also Early Wisconsin, thus implying that many deposits assigned dates of about this value may be of Early Wisconsin age.

ACKNOWLEDGMENTS

This paper has been critically read by R. P. Goldthwait whose suggestions are acknowledged with thanks. We are also indebted to W. J. Wayne, of the Indiana Geological Survey, for making available to us results of some of his work on Pleistocene molluscan faunules in Indiana in advance of publication.

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Theophrastus on Stones. *Earle R. Caley* and *John F. C. Richards.* The Ohio State University, Graduate School Monographs, Contrib. in Physical Science, No. 1. vii+238 pp. 1956. $6.00.

Until now, translations of Theophrastus in English were out of date and out of print. Professors Caley and Richards deserve our thanks for making this work available again and for revealing, through their commentaries, the wealth of information contained in this ancient Greek treatise. The translation is highly readable by itself because of the light it sheds on Greek knowledge of minerals and rocks twenty-three centuries ago. The commentary makes it extremely valuable because it takes up the important statements in the text and explains them in the light of twentieth-century knowledge of the nature and distribution of the minerals and rocks involved. Professor Caley's knowledge of mineralogy and chemistry brings out the nature of *alabastrites, anthrax, smaragdos, chrysokolla, iaspis,* and many others from the meager descriptions of Theophrastus. These minerals and rocks and many others do not correspond to their modern analogues, alabaster, coal, emerald, chrysocolla, and jasper; they are more general in meaning and, in the case of *anthrax,* coal is not meant at all, but a red precious stone. As we read the commentary, we feel that we are being guided by expert hands and that we are getting the full meaning of Theophrastus' text.

This book is a valuable contribution to the early history of science, in particular to the early history of chemistry, mineralogy, geology, and economic geology. The Graduate School of The Ohio State University is to be congratulated for sponsoring this publication and for sparing no effort to ensure good, clear printing and pleasing appearance of this volume. It is an example of fine printing as well as of scholarly achievement.

A. La Rocque

RANGE EXTENSION OF *EUMECES FASCIATUS* (SCINCIDAE) INTO SANDUSKY COUNTY, OHIO

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On August 22, 1956, Earl Cranston and I collected a specimen of *Eumeces fasciatus* near Vickery in Sandusky County, Ohio (see fig.). It was apparently sunning itself on a fallen fence post a few feet from the Miller Blue Hole stream on the east side of the State owned Miller Blue Hole property. This specimen is 77 mm. long including tail, or 32 mm. from snout to vent. It is in my collection at the Department of Zoology and Entomology, The Ohio State University.

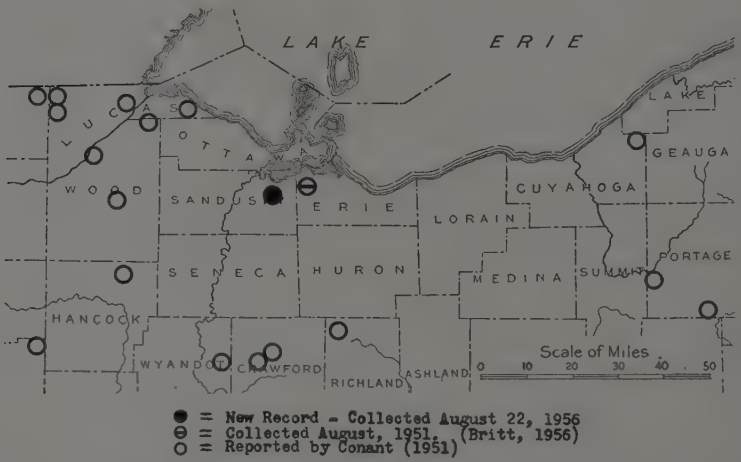

FIGURE 1. Map of North Central Ohio showing localities where *Eumeces fasciatus* has been collected. (For records for remainder of State see Conant, 1951).

In his distribution map of this species, Conant (1951, 269) showed that it is fairly evenly distributed over Ohio except for an area made up of several counties bordering or near the western end of Lake Erie and extending fanlike to include most of the eastern and southeastern counties. Since Sandusky and Erie Counties are included in this area, apparently no collections of *Eumeces fasciatus* had been reported from these counties prior to 1951.

In August of 1951 I collected a specimen near Castalia in Erie County (Britt, 1956). In the summer of 1952 I observed a specimen, estimated to be five to six inches in total length, on the trunk of a hollow willow tree (Salix) located on the south side of the Miller Blue Hole. This site was approximately two hundred yards from the place where the August 22, 1956, collection was made.

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THE INSEMINATION OF BODY CAVITY AND OVIDUCAL EGGS OF AMPHIBIA

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After exposure to sperm suspension, body cavity eggs of *Hyla crucifer*, *Bufo fowleri*, and *Rana pipiens* frequently exhibit various cortical changes such as crinkling, indentation, pigment migration, or flattening; but in all cases the eggs subsequently deteriorate. Oviducal eggs, however, which have passed through the expanded infundibulum (essentially a part of the body cavity) and the ostium the abdominal orifice may develop when inseminated (Born, 1892; Rugh, 1935, 1948; Good and Daniel, 1943; Aplington, 1949).

Inability to obtain normal development in amphibian eggs removed from the body cavity and exposed to sperm suspension has puzzled investigators since the late 1800's. Although a reservoir of unpublished information exists, published literature on the subject is meager. Barthélémy (1922) reported the initiation of development in appropriately treated[1] body cavity eggs of *Rana fusca* by pricking them with a needle dipped in blood or sperm although immersion in sperm suspension was unsuccessful. Born (1892) stated that an inseminated body cavity egg of *Triton taeniatus* attained the morula stage of development. Good and Daniel (1943), working with *Triturus torosus*, obtained irregular cleavage in a small percentage of fertilized coelomic eggs, one of which reached the neurula stage. Bearing on the problem is the work of Bataillon and others concerned physiologically with the activation of oviducal eggs (Bataillon and Tchou Su, 1930). Rugh (1948) comments that whether the answer to this dilemma rests within the jelly, or with changes in the egg, or with both, has not yet been determined. Indications are that both are concerned, as Good and Daniel (1943) found that the artificial addition of oviducal jelly to coelomic eggs markedly increased the number of eggs showing segmentation. They also found that between ovary and cloaca there is a rearrangement of yolk platelets in the egg, and that in fertilized coelomic as contrasted with fertilized oviducal eggs cleavage is much delayed and slower.

If amphibian eggs are regarded as mature when they have been surrounded with their full complement, *i.e.*, several layers of oviducal jelly, eggs taken from the body cavity or from the upper half of the oviduct are immature. Nevertheless, the transition is so abrupt between jellyless, non-fertilizable body cavity eggs and oviducal eggs fertilizable when only one layer of jelly is present that certain questions are warranted, particularly, are amphibian body cavity eggs immature either chromosomally or cytoplasmically as compared with oviducal eggs, and what is the role of the oviduct? The present paper is an attempt to supply answers to these questions on a morphological basis.

It is hoped that this material may be of use to other investigators who cooperatively may find the complete solution to this problem.

CHROMOSOMAL MATURITY

For the identification of chromosomes during maturation, five to twenty eggs from each of several representative regions of the reproductive tract of normally ovulating *Hyla crucifer*, *Bufo fowleri*, and *Rana pipiens* were fixed in P.A.F.,

[1]Immersion for 20–30 hours at laboratory temperature either in aerated grenouille serum or in a solution of NaCl, 7 parts in 1000 parts of dist. water, or the latter alkalinized with NaOH to p. 200,000.

sectioned at 8 microns, and stained in Delafield's hematoxylin. Slides were then washed, decolorized in 1.0 percent HCl, washed, stained with eosin, washed, immersed in 1.0 percent NH_4OH, washed, and dehydrated. This procedure colors the yolk platelets pink in contrast to the chromosomes, which retain the hematoxylin.

Stages of maturation attained by *H. crucifer*, *B. fowleri*, and *R. pipiens* eggs here studied, during their passage from ovary to lower oviduct (includes uterus) are reported in table 1.

TABLE 1

Maturation of Bufo fowleri, Hyla crucifer *and* Rana pipiens *eggs in different regions of the reproductive tract*

Amphibian	Resolution of germinal vesicle	First polar spindle	First polar body formed	Second polar spindle
Bufo fowleri	ovary			
	ovulation	body cavity	body cavity	body cavity
		upper oviduct	upper oviduct	upper oviduct
Hyla crucifer	ovary	ovary	ovary	ovary
		body cavity	body cavity	body cavity
Rana pipiens	ovary			
	ovulation	body cavity	body cavity	
		upper oviduct	upper oviduct	upper oviduct
			middle oviduct	middle oviduct

Prophase changes, including resolution of the germinal vesicle, occur when the egg is still in or just leaving the ovary. In the several ovulating *Hyla* utilized, all eggs formed the second polar spindle either in the ovary or in the body cavity (fig. 1 and 2); eggs of *Bufo* attained this condition either in the body cavity or in the oviduct. In *Rana pipiens*, about one egg in ten formed a first polar body in the body cavity, usually near the infundibulum. The great majority formed the first polar body and second polar spindle in the upper or middle oviduct.

Once initiated, nuclear changes from germinal vesicle to second polar spindle appear to proceed quite independently of the location of the egg in its passage to the lower oviduct. There is clearly no inhibition of maturation in the body cavity of *Hyla*. Conversely, there is no apparent oviducal impetus to maturation in *Rana* because when the oviducts of *Rana* are ligated, eggs forced to remain in the body cavity go on to form a second polar spindle.

The heading "second polar spindle" is included in table 1 chiefly because it is employed in other studies on maturation reported in the literature. While there is an appreciable interval between resolution of the germinal vesicle and the expulsion of the first polar body (total time 2 to 4 hours, Le Brun, 1902) an interphase stage between the formation of the first polar body and the second

EXPLANATION OF FIGURES IN PLATE I

All figures X1550. Longitudinal axes of spindles 0.02 to 0.03 mm.

1. Ovarian egg of ovulating *Hyla crucifer*, showing first polar spindle and follicle cells. (The follicular sheath was torn at this point. These cells were superimposed from another section.)
2. Body cavity egg of *Hyla crucifer*, showing first polar body and second polar spindle.
3. Uterine egg of *Rana pipiens* (induced ovulation), abnormally in first polar spindle. This egg was fixed in P.A.F. 6 minutes after insemination.
4. Normal uterine egg of *Rana pipiens*, showing first polar body and second polar spindle.

1
2
3
4

TABLE 2

Maturation of amphibian eggs in different regions of the reproductive tract

Amphibian	Resolution of germinal vesicle	First polar spindle	First polar body	Second polar spindle	Investigator
Axolotl (*Ambystoma tigrinum*)		body cavity? upper oviduct	 upper oviduct middle oviduct	 lower oviduct	Jenkinson, 1905
Bombinator igneus	ovulation	body cavity	 upper oviduct		Le Brun, 1901, 1902
Bufo americana	ovary	body cavity	 upper oviduct middle oviduct		King, 1901
Bufo vulgaris	ovary	ovary	ovary	ovary	Le Brun, 1901, 1902
Cryptobranchus allegheniensis	ovulation	ovary body cavity oviduct	ovary body cavity oviduct	 lower oviduct	Smith, 1912
Hynobius retardus	ovulation	body cavity? upper oviduct	 upper oviduct	 lower oviduct	Makino, 1934
Rana fusca (temporaria)	ovary	ovary body cavity	 body cavity	 oviduct	Wagner, 1923
Rana fusca (temporaria)	ovulation	body cavity upper oviduct		 lower oviduct	Le Brun, 1901, 1902
Rana pipiens	ovulation	body cavity	 oviduct	 uterus	Rugh, 1948
Triton alpestris	ovary	body cavity upper oviduct	 upper oviduct middle oviduct	 lower oviduct	Carnoy and Le Brun, 1899
Triton alpestris	ovary	upper oviduct	upper oviduct		Le Brun, 1901, 1902
Triton cristatus	ovary	upper oviduct	upper oviduct		Le Brun, 1901, 1902
Triton taeniatus		body cavity	body cavity upper oviduct		Born, 1892
Triton taeniatus	ovary	body cavity upper oviduct	 middle oviduct	 lower oviduct	Le Brun, 1901
Triton torosus	ovulation	body cavity upper oviduct	body cavity upper oviduct	body cavity upper oviduct lower oviduct	Le Brun, 1902
Triton torosus	ovary	body cavity	body cavity upper oviduct	body cavity upper oviduct	Good and Daniels, 1943
Triturus viridescens	ovulation	body cavity	 upper oviduct		Jordan, 1893

polar spindle is apparently of short duration. Such a stage is seldom figured in the literature, and when it is (Carnoy and Le Brun, 1899, fig. 14 and 15; Le Brun, 1902, fig. 38) there is merely a transient massing of the chromosomes without the formation of a nuclear membrane. Moreover, in the hundred or more body cavity and upper oviduct eggs here studied, no interphase condition following polar body 1 was found. For experimental purposes it seems reasonable to regard an egg from which polar body 1 has been expelled as being already in the second polar spindle, and these headings in table 1 are considered as essentially identical.

A summary of published accounts of egg maturation in amphibia with reference to the location of the egg during its reproductive passage is presented in table 2.

As in table 1, prophase changes are seen to occur uniformly when the egg is still in or just leaving the ovary. Beyond this point the data are best interpreted in the light of other facts concerning ovulatory phenomena. First, although the time of onset of ovulation is sudden in a given individual, the liberation of eggs from the ovary occurs gradually. Eggs ovulated later in the reproductive period are found to be in later stages of maturation than eggs ovulated early (Smith, 1912, *Cryptobranchus*).[2] Second, chromosomal maturation is proceeding in body cavity eggs which travel different distances to reach the ostia and which often must wait their turn at the crowded infundibulum before entering the oviduct.

The *Hyla crucifer* (table 1) and *Bufo vulgaris* (table 2), in which all maturation stages occurred in the ovary, were probably individuals examined late in their ovulatory cycle. In cases where the same species has been studied by two investigators and observations differ (*R. fusca*, *R. pipiens*, *T. alpestris*, *T. taeniatus*, *T. torosus*), the reported differences are probably a function of the variables outlined; and where no variability is reported (*B. igneus*, *B. vulgaris*, *R. pipiens* (Rugh), *T. alpestris* (Le Brun), *T. cristatus*, *Triturus viridescens*), it is likely that if larger numbers of eggs or individuals were examined differences in maturation time would be found also in these forms.

From an overall point of view it seems clear that in ovulating amphibia, some eggs mature to second polar spindle after entering the oviduct and are thus chromosomally immature in the body cavity while others mature to second polar spindle before entering the oviduct. It is the latter which are of particular interest because in this group are body cavity eggs which never develop following insemination but are chromosomally indistinguishable from oviducal eggs which usually fertilize and develop.

CYTOPLASMIC MATURITY

Although chromosomal maturation proceeds continuously from ovary to oviduct, by contrast, body cavity eggs exhibit cortical or cytoplasmic immaturities which are alleviated only after the egg enters the oviduct.

Unlike the eggs of *Triton*, *Triturus*, and other salamanders which are normally polyspermic (Frankhauser, 1941), oviducal eggs of Anura are monospermic. In *Rana* and *Hyla*, however, body cavity eggs in sperm suspension may be penetrated by many spermatozoa (up to 22 detected), visible with the Feulgen technique against the background of pigment granules and colorless yolk platelets. As observed under the dissecting microscope, puncture points can sometimes be identified in the eggs of *Rana pipiens* by minute streams of yolk platelets which flow outward into the water. It might be expected, a priori, that fertilization of coelomic eggs in the normally polyspermic salamanders would have a greater chance of success but such is not the case (Good and Daniel, 1943). Evidently

[2]There is some indication, unsubstantiated by definite proof, that in induced as contrasted with normal ovulation, the overall ovulation period is shorter and the stage of chromosomal maturation more uniform.

there is a change in the cortical properties of both Urodele and Anuran eggs after they enter the oviduct.

Following insemination a few eggs in any batch (*Rana*, *Hyla*) may undergo a brief period of abnormal and superficial "cleavage" confined to the upper hemisphere of the egg. Such eggs when sectioned show irregular concentrations of pigment granules reminiscent of sperm penetration paths, and vacuolization (apparently a degenerative phenomenon) of the cytoplasm. Several of these "cleavage eggs" (*Rana*) contained nuclear centers with atypical masses of chromosomes, while in others the egg chromosomes remained in second polar spindle metaphase, becoming atypical as the egg deteriorated. Chromosomes, if any, evolved from penetrating spermatozoa could not be identified. Other visible changes in these eggs (*Rana*, *Hyla*) are the downward migration of pigment until the egg (uncleaved) approximates the appearance of an early yolk plug stage, and flattening or mushrooming of the whole egg. The latter condition is somewhat less pronounced when the eggs are supported on jelly. Generally speaking, the smaller, lighter eggs of *Hyla* gave fewer abnormalities than eggs of *Rana*. Eggs of *Bufo fowleri* are less satisfactory to use because their heavy pigmentation cuts down visibility.

One *Hyla* egg attained what can possibly be regarded as an advanced stage of cleavage (fig. 5 and 6) because a number of the cells contained nuclear centers. But even in this case, the cleavage was abnormal in its largely peripheral distribution and irregularity in cell size.

Thus, macroscopic and microscopic evidence would seem to indicate that the failure of body cavity eggs to fertilize should be attributed to cortical or cytoplasmic rather than to chromosomal immaturity.[3]

THE ROLE OF THE OVIDUCT

In contrast to body cavity eggs, eggs taken from any region of the oviduct and fertilized in pond water or .1 Ringer's solution may develop (Rugh, 1935, 1948). It is my observation that in the critical region of the oviduct, *i.e.*, in the upper several centimeters where conditions are transitional, the number of eggs which fertilize diminishes as the ostium is approached. In this region the eggs are much crowded, the first layer of jelly is scarcely complete, and any manipulation is damaging. When immersed in sperm suspension, the surface of these eggs crinkles as does that of body cavity eggs, and in non-fertilizable eggs punctures are occasionally produced. When the first layer of jelly is completed and the second added as the egg proceeds down the oviduct, the cortex (? egg membrane) becomes firmer, crinkling disappears, puncture points never occur, and the pigment appears more sharply delineated. While some eggs abruptly acquire the capacity to be fertilized, others are somewhat slower to do so.

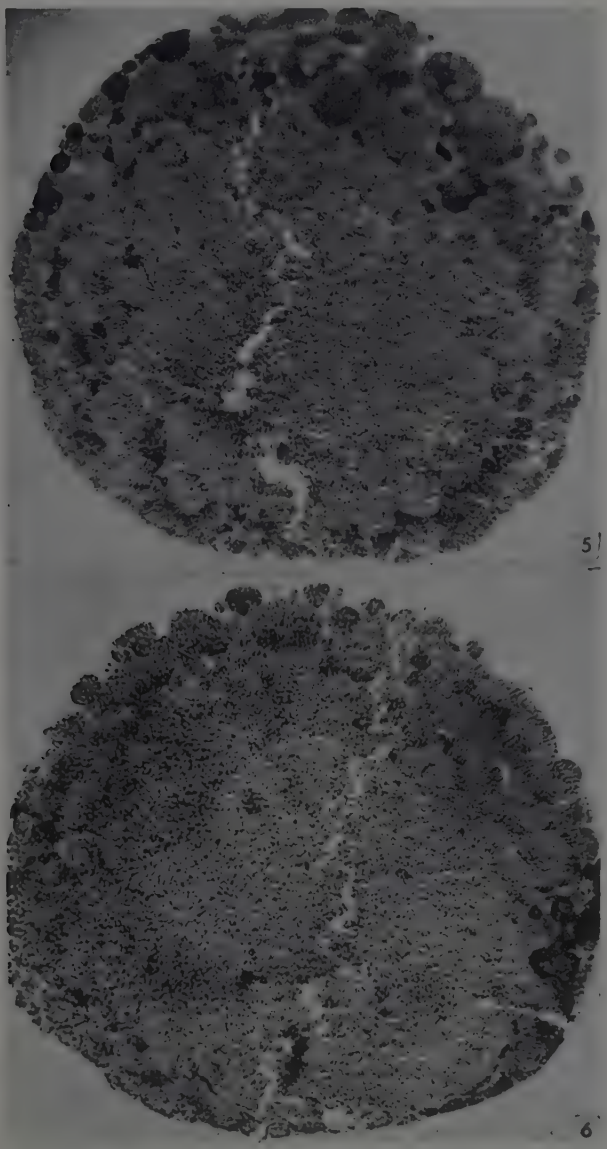
It may be argued that in *R. pipiens* and *B. fowleri* the lowered percentage of

EXPLANATION OF FIGURES IN PLATE II

Figures X130

5 and 6. Two sections through an inseminated body cavity egg of *Hyla crucifer*. Nuclear centers (not visible at this magnification) were present in a number of the cells. Note irregular and peripheral cleavage and pseudo-cleavage.

[3] It is known that histochemical changes, *e.g.*, the redistribution of sulphydryl compounds and RNA occur in the egg following the breakdown of the germinal vesicle, but at the present time these changes are not well understood. Whether, as seems likely, they contribute to the cytoplasmic maturity of the egg including the establishment of bilateral symmetry, whether their distribution is aided by egg rotation in the oviduct, etc., remains hypothetical. See Fankhauser (1948).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fertilization in the upper few centimeters of the oviduct is traceable to eggs which are chromosomally immature, but this is certainly not the case in *H. crucifer* where body cavity and oviducal eggs were chromosomally alike. Furthermore, in *Rana pipiens* uterine eggs aberrantly in an earlier stage of maturation than many body cavity eggs will fertilize and develop normally. This was accidentally discovered in one batch of eggs (induced ovulation) of which half were stripped into fixative, the rest inseminated and allowed to develop. On examination the former exhibited not the expected second polar spindle (fig. 4) but a first polar spindle (fig. 3). The chromosomes were clearly tetrads; no polar body was present.

Whatever the conditioning effect of the oviduct on the egg may be, it is not species specific, at least between *B. fowleri* and *R. pipiens*. When ovaries are removed from a non-ovulating *R. pipiens* and body cavity eggs from a normally ovulating *B. fowleri* are transferred by pipette to the *pipiens* body cavity, these eggs on passing through the oviduct fertilize and develop after insemination with *fowleri* sperm suspension. They will also develop when taken from different regions of the oviduct. Coelomic eggs of *R. pipiens*, placed in the *B. fowleri* body cavity, recovered from the oviduct and inseminated with *R. pipiens* sperm suspension, will also develop normally.

SUMMARY

1. After exposure to sperm suspension, body cavity eggs of *Hyla crucifer*, *Rana pipiens*, and *Bufo fowleri* subsequently deteriorate. Oviducal eggs, however, may develop following insemination. The transition between jellyless, non-fertilizable body cavity eggs and upper oviduct eggs fertilizable when only one layer of jelly is present is rapid.

2. On a morphological basis, it is suggested that the failure of body cavity eggs to fertilize is attributable to cytoplasmic rather than to chromosomal immaturity.

3. Cytoplasmically: inseminated body cavity eggs may exhibit polyspermy instead of normal monospermy (anura), yolk platelet extrusion, abnormal and superficial cleavage, unusual pigment migration, crinkling, and flattening. These conditions are remedied as the egg receives its first coat of jelly in the upper oviduct.

4. Chromosomally: in *Hyla crucifer*, body cavity eggs may complete their maturation before entering the oviduct; in at least 6 other species of amphibia some body cavity eggs are in the same stage of maturation as some oviducal eggs, and in *Rana pipiens*, although normally fertilized when in second polar spindle, eggs in the first polar spindle will fertilize only after they have entered the oviduct.

5. The role of the oviduct is shown to be non-specific. Between *B. fowleri* and *R. pipiens* reciprocal transfer of body cavity eggs followed by their recovery from the oviduct and fertilization in parental sperm suspension results in normal development.

6. Published accounts of maturation in amphibia are summarized and discussed.

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Microscopic Petrography. *E. Wm. Heinrich.* McGraw-Hill Book Company, Inc., New York. 1956. xiii+296 pp. $6.50.

This work is intended as a reference volume for practicing geologists, as well as a textbook for students at the initial or intermediate level. The author has furthered his aim by not proposing any new rock names, and keeping the varietal names to a minimum.

The book is mainly a series of detailed petrographic descriptions of the more common rocks. Under each type there is a systematic breakdown into the following categories: definitions, textures and microstructures, petrologic and geographic occurrences, and mineralogy. This logical arrangement greatly facilitates use of the book for reference purposes. More than 125 photomicrographs accompany the descriptions. These, with occasional microdrawings, give the reader an excellent characterization of each rock type.

The author does not include comprehensive classification tables to aid students—nor is there any attempt to give references to original sources. Such references as appear are limited to standard textbooks, and a few articles on the use of the universal stage and preparation of thin sections.

During a discussion on the sequence of crystallization of igneous rocks (p. 26), it is stated that in the general case, the minerals, ilmenite, apatite, magnetite, zircon, and sphene are among the first to form. Although this is assumed to be true by many petrologists, it is contrary to the recent findings of Prince, Moorhouse, and others.

In addition to descriptions of rock types, the author discusses micrometric analyses, staining, and insoluble residue and heavy mineral techniques. Aside from the very minor criticisms mentioned above, this book can be described as an excellent contribution to the field of petrography. The wealth of detail, as well as the lucid presentation, should strongly appeal to both the student and the practicing petrographer.

ERNEST G. EHLERS

Man's Role in Changing the Face of the Earth. *William L. Thomas, Jr.*, Ed. University of Chicago Press. 1956. xxxviii+1,193 pp. $12.50.

This impressive volume includes the background papers and a censored version of an international symposium held during June, 1955, at Princeton, New Jersey, under the sponsorship of the Wenner-Gren Foundation for Anthropological Research. The papers from 53 of the 70 participants are those distributed in advance of the sessions. The abbreviated record is from the week-long series of discussions among the varied specialists (about 40% earth-scientists, about 28% biologists, about 12% social-scientists, and the remaining 20% from applied-fields) from 10 countries.

The aim was to have a conference of amateurs and to make no serious attempt at coordination, much less synthesis. As might be expected, the result is a wealth of both highly abstract and middle-level ideas and of supporting detail. At best, the net effect is to stir the imagination rather than to increase the reader's disciplined intellectual control in the field being analyzed.

Part I, Retrospect, has 18 chapters, of which two (by Carl O. Sauer and Alexander Spoehr) can only be described as excellent, rich in both philosophical and operational types of ideas. Eight other chapters (by Clarence J. Glacken, Omer C. Stewart, Karl A. Wittfogel, Hermann von Wissmann, Soliman Huzayyin, Pierre Gourou, James C. Malin, and Lewis Mumford) are very good, full of stimulating ideas. The remaining chapters are more suited to encyclopedic or monograph type usage. All four sessions of the Retrospect part of the symposium—Man's Tenure of the Earth (chairman, F. Fraser Darling), Subsistence Economics (Alexander Spoehr), Commercial Economics (Paul B. Sears), and Industrial Revolution and Urban Dominance (Kenneth Boulding)—seem to have been stimulating to the participants, and should be to the reader.

On the whole, the several dozen chapters in Part II, Process, are disappointing, as nearly half are overwhelmingly factual in nature and only half a dozen (by Richard J. Russell, Edgar Anderson, Edward L. Ullmann, Paul B. Sears, Andrew Clark, and Donald H. McLaughlin) appear worthy of appraisals excellent or very good in terms of thought provoking content. The symposium discussions—Changes in Physical Phenomena (chairman, Alan M. Bateman), Changes in Biological Communities (Marston Bates), and Techniques of Learning: Their Limitations and Fit (Edgar Anderson and Sol Tax)—also varied widely in quality, with the last named arousing the most favorable reaction in this reviewer.

Part III, Prospect, had seven chapters, mostly very good or good in terms of mental stimulation (those by Sir Charles G. Darwin and F. S. C. Northrop being particularly challenging). The symposium discussions—Limits of the Earth: Materials and Ideas (chairmen, Joseph H. Willits and Lester E. Klimm), Man's Self-Transformation (Lewis Mumford), the Unstable Equilibrium of Man in Nature (Harrison Brown)—were very thought provoking and laid the ideological groundwork for fruitful coordination and attempted synthesis in the future.

The co-chairmen of the symposium Carl O. Sauer, Marston Bates, and Lewis Mumford – summarized respectively the three sessions, Retrospect, Process, and Prospect, in the closing meeting. All three are high caliber, with those by Bates and Mumford being especially appropriate in summing up the strengths and weaknesses of current philosophies and methods of attack on land-use problems.

The idea of this international symposium was apparently conceived by William L. Thomas, Jr., of the Wenner-Gren Foundation, and the one week symposium followed nearly three years of planning, conferences, and preparations. About half of the background papers and session discussions seem to be concerned more with meticulous analysis than as first attempts leading to coordination and synthesis, but even so there is more real attempt at the latter in this volume than in anything else conveniently available to the layman.

LAWRENCE A. HOFFMAN

Risk and Gambling. *John Cohen* and *Mark Hansel.* Philosophical Library, Inc., New York. 1956. x+153 pp. $3.50.

The book's subtitle, "The study of subjective probability," clearly delimits its scope. The authors' concept of the term may be judged from ". . . the most diverse of our activities may share some common characterwhich we may refer to as a risk-taking character . . ." and "Risk-taking may regarded as subjective probability in action."

Numerous empirical studies are reported in detail. Some involve the way children and adults predict the outcomes of events determined by chance. Others deal with variations in meanings associated with words like rarely, seldom, and often. Still others describe behavior in situations where some real risk is involved, such as the loss of a pedestrian life in traffic or the loss of a fortune at gambling tables.

Throughout the work a conspicuous attempt is made to apply objective study methods to the subject. The book will most likely appeal chiefly to psychologists and other students of human behavior.

WILLIAM B. MCINTOSH.

SOUND PRODUCTION AND ASSOCIATED BEHAVIOR IN INSECTS[1]

RICHARD D. ALEXANDER

Department of Zoology and Entomology, The Ohio State University, Columbus 10

The number and variety of insects which produce sounds with specialized apparatus undoubtedly exceed those of all other living organisms combined, but only a few of these, the crickets, katydids, grasshoppers, and cicadas, make noises loud enough to be noticeable to man. These are the so-called singing insects, and their ancestors may well have been the first organisms on earth to communicate through sound waves transmitted in air.

Although often obscured today by the intense and endless noises of civilization, insect sounds must have been among the loudest and most persistent sounds heard by primitive man. Their effect is apparent in art, mythology, and literature, and it may be more than mere coincidence that the chant, often called the most ancient of human music, bears a striking resemblance to the tuneless and repetitious insect song.

Scientific interest in insect sounds dates at least to Aristotle, who over two thousand years ago separated two groups of Homoptera on the basis of whether or not they could produce sounds (Myers, 1929, p. 81). Today a complete bibliography on sound production and perception in insects would contain several thousand references.

Until recently, studies of insect sounds had to be based on human auditory impressions. For this reason, the variety and complexity of structure in insect sounds, chiefly involving pulsations delivered too rapidly for the human ear to perceive, are only beginning to be realized. Magnetic tape recorders and electronic sound analyzing devices now provide objective means of analyzing and comparing these intricacies of structure, and have been responsible for a surge of interest in insect sounds in many different parts of the world (Busnel, 1954; Pringle, 1956).

Potential applications of studies of insect sounds are many and varied. Insect sounds have long been used in systematics (Fulton, 1931, 1932, 1952; Davis, 1928; Pringle, 1955), and in studies of ecological and geographical distribution (Faber, 1929, 1932); they show promise of being valuable in control (Robertson, 1944; Kahn *et al.*, 1947; Kahn and Offenhauser, 1949; Vanderplank, 1948; Busnel, 1956), and in fundamental studies of behavior and physiology (Pringle, 1954, 1956).

Sound production and perception have arisen in the insects a large number of times, and consequently a wide variety of structures is involved (Kevan, 1954). Sounds are produced by insects in five different ways: (1) by rubbing one body part against another, *i.e.*, stridulation (crickets, katydids, grasshoppers, bugs, beetles, moths, butterflies, ants, caterpillars, beetle larvae, others); (2) by striking some body part, such as the feet (band-winged grasshoppers), the tip of the abdomen (cockroaches), or the head (death-watch beetle) against the substrate; (3) by vibrating some body part, such as the wings, in air (mosquitoes, flies, wasps, bees, others); (4) by vibrating drum-like membranes called tymbals (cicadas,

[1]This study has been supported by grants from The Ohio State University Development Fund, The Graduate School of The Ohio State University, and The Rockefeller Foundation. The author expresses appreciation to Dr. Donald J. Borror of the Department of Zoology and Entomology of The Ohio State University for advice and assistance.

leafhoppers, treehoppers, spittlebugs); and (5) by forcibly ejecting air or fluid (short-horned grasshoppers).

The auditory organs of insects generally involve tympanal organs or hair sensilla. They differ from those of mammals and birds in being relatively insensitive to fluctuations in frequency, but are apparently capable of responding to high-speed intensity modulations (Pumphrey, 1940). It is in this character of rhythm and speed of pulsations that a wide variety of patterns exists, both in the sounds of different species of insects, and in the different sounds of a single species. The ability of an insect to discriminate between the various rhythms of its own species, or to single out the sounds of its own species from those of others is largely untested, and represents one of the most fascinating aspects of the study of insect acoustics.

Sound-producing and auditory structures may involve almost any part of the insect's exoskeleton. In different groups, such organs have been found on the mandibles (Acrididae), palpi (Tridactyloidea), antennae (Phasmidae), head capsule (Anobiidae), pronotum (Cerambycidae), mesonotum (Elateridae), metanotum (Prophalangopsidae), forelegs (Tettigonioidea), middle legs (Lucanidae), hind legs (Passalidae), forewings (Tettigonioidea, Acridioidea), hind wings (Acridioidea), several of the abdominal segments (Coleoptera, Orthoptera, Homoptera), and the cerci (Blattidae). Many species possess two sets of sound-producing organs (Corixidae) or auditory organs (Gryllidae).

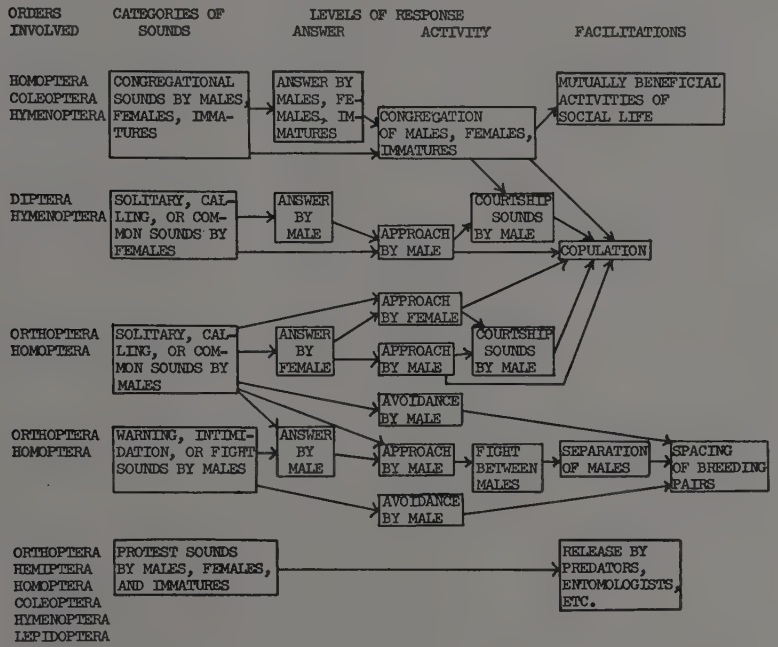
Insects produce sounds in two general types of situations. First, there is a group which includes the crickets, katydids, grasshoppers, cicadas, leafhoppers, and possibly many others, the adult males of which produce sounds more or less continuously throughout daily periods which are apparently determined by light intensity and possibly by temperature or humidity or both. The sounds produced by some of these insects are the loudest and best-known of insect sounds, and are those that we have come to call "songs," probably because they generally consist of rhythmical repetitions of the same phrases. Since these songs are the insect sounds which are most often heard, they have received such labels as "common" songs and "ordinary" songs. They have also been called "solitary" songs since in the singing Orthoptera they are often inhibited by the presence of other organisms (situations involving other organisms evoke sound responses of different nature). They function in bringing the adult males and females into close proximity (at least in some species), either by (1) causing the female to move to the male (crickets), (2) causing the female to make a sound which attracts the male and enables him to locate her (slant-faced grasshoppers), or (3) causing congregation of large numbers of males and females (cicadas). Knowledge of these functions has caused such names as "calling" songs and "congregational" songs to be applied to these sounds.

The second general type of stimulus situation includes those situations in which the sound is elicited directly as a result of the presence or activities of other organisms. The sounds produced in such situations can be divided into four categories: (1) those produced by males, females, or immatures as a result of the presence or activities of animals of other species disturbing, capturing, or holding them and referred to by such terms as "alarm" cries, "distress" calls, "protest" sounds, or "congregational" sounds; (2) those produced by a male in the presence of a female of the same species, generally called "courtship" or "mating" songs; (3) those produced by a male in the presence of another male of the same species, generally called "warning," "intimidation," or "fight" sounds; and (4) those produced by a female in the presence of a male of the same species.

The types of behavioral sequences that have been observed in connection with sound production in insects are summarized in textfigure 1. Sounds placed in the same categories because they are produced in similar situations often occur

in several different orders. These are not homologous, however, and in many cases sounds in the same category have arisen independently a number of times within a single order or family. Specialized sound production that probably has a common origin in two or more families is known in only two orders, the Orthoptera and the Homoptera.

To illustrate some of these different kinds of sounds and the situations in which they are produced, representatives of three orders are discussed below.



TEXT FIGURE 1. Behavioral sequences associated with insect sounds.

All sounds were recorded at a tape speed of 15 inches per second, the cricket and beetle sounds with a Magnecorder, Model PT6A, the cicada sounds with a Magnemite, Model 610EV. An American Microphone Company D33A microphone was used for all recordings. The audiospectrographs, or Vibragrams (Plates I to IV) were made with a Vibralyzer, the use of which is explained by Borror and Reese (1953). In all Vibragrams displayed here, frequency is portrayed on the vertical axis, time on the horizontal axis, and relative intensities by the darkness of the mark. The sound pulses portrayed in figure 1 are of a relatively pure frequency, making at this particular setting of the Vibralyzer approximately the same type of mark as would electronically produced pure frequency signals. The wide range of frequencies which appears in figures 4 to 6 is also present in the sound portrayed in figure 1 but is masked by the dominant pure frequency. As this dominant pure frequency disappears from the sound (transition to courtship), a stepping-up of the gain to produce a comparably dark picture brings out the soft frequencies.

Acheta assimilis *Fabricius*[2]
(*Orthoptera: Gryllidae: Mountain Field Cricket*)

The sounds of field crickets are produced by vibration of the tegmina, or forewings. As the tegmina are closed, a transverse row of minute teeth (file) on the lower side of the upper tegmen near its base is scraped by a dorsally-projecting sharp-edged structure (scraper) on the median edge of the lower tegmen. In the calling song the tegmina are held at a 45° angle with the body; in courtship they are lowered and tilted roof-like over the abdomen. In the calling song of the mountain field cricket (fig. 1), the tegmina are vibrated at a rate varying from 15 strokes per second at 50° F to 29 strokes per second at 100° F. A concomitant change in the dominant frequency occurs, indicating that this pure frequency is a function of the speed of wing motion, and probably corresponds to the number of file teeth struck per second, as suggested by Lutz and Hicks (1930).

If a culture of field crickets containing several adult males and females is kept under observation, it is soon noted that some sort of sound is being produced by one or more of the males almost continually. A few distinct types of sounds gradually become apparent to the observer, as do the situations in which they are produced. Eventually one becomes able to describe relative positions of different individuals in the culture and the types of activity in which they are engaged without looking at them solely by the types of sounds being produced by the males.

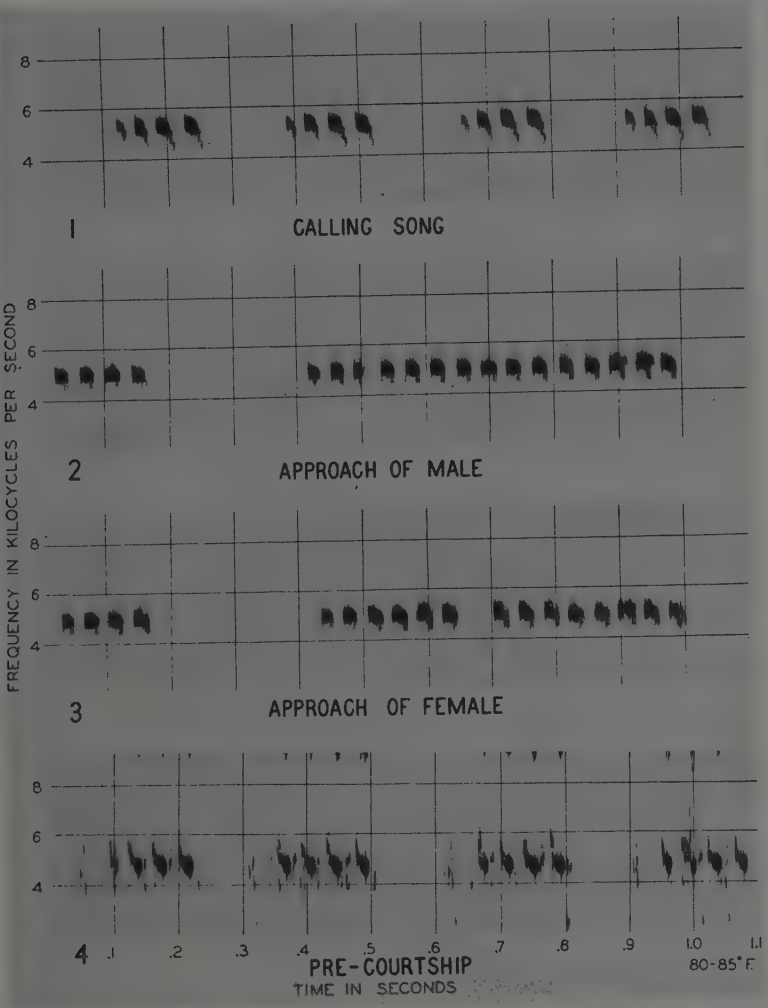
As with most singing Tettigoniidae and Gryllidae, male field crickets tend to space themselves in the field, and to remain in one spot all their adult lives. A large part of the time, both day and night, they produce the calling or solitary song (fig. 1). This song attracts the females, which move toward and locate the males.

When a singing male is approached by another male, he stops the regular chirping of the calling song and delivers one or more louder, clearer, and longer chirps[3] (fig. 2). The two individuals may stand an inch or so apart, facing each other, and chirp in this manner for several seconds, or they may move together and engage the mandibles and scuffle, sometimes turning and kicking each other with the hind legs. Eventually one male leaves, sometimes after only exchanging chirps, sometimes after physical contact in which he may lose a leg or have his tegmina torn.

When a male singing the calling song is approached by a female, or sometimes when a male walking around his "territory" encounters a female, he will usually produce a few chirps very similar to those produced when another male is encountered *i.e.*, loud, clear chirps containing a large number of pulses (fig. 3). The chief difference between this type of chirping and that produced in an encounter between males is that it grades continuously into what has been arbitrarily designated as "pre-courtship singing" (fig. 4) and, if uninterrupted, eventually into "mixed courtship singing" (fig. 5), and "full courtship singing" (fig. 6). Pre-courtship singing is made up of softer, less musical chirps than those produced in the calling song, and mixed courtship singing consists of a mixture of the soft pulses produced in full courtship with louder, clearer pulses resembling those of the calling song. Full courtship singing consists of a rhythmical repetition of

[2]The several species of native *Acheta* (field crickets) in North America have thus far been designated by colloquial names only. The individuals discussed here were from the spring brood of the mountain cricket of Fulton (1952), and were collected in Franklin County, Ohio.

[3]The term "chirp" is an English word of common usage denoting any short, sharp animal sound, and has been generally used by entomologists to refer to intermittent types of stridulation as contrasted with more or less continuous trilling. In the present paper the term "pulse" will be used to refer to the sound made by a single movement of the sound-producing apparatus, and "chirp" will refer to short groups of pulses (fig. 1 portrays four 4-pulse chirps).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CALLING SONG
FREQUENCY IN KILOCYCLES PER SECOND
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APPROACH OF MALE
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APPROACH OF FEMALE
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.7
.8
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1.0
1.1
PRE-COURTSHIP
80-85° F.
TIME IN SECONDS

many-pulse chirps, each of which terminates in a louder, clearer "tick," represented in figure 6 by the slender vertical mark between pulse groups.

Mixed courtship singing is the type of courtship most commonly heard in a culture. It apparently represents a stage between pre-courtship and full courtship which is maintained for long periods of time when the female is not fully stimulated by the courtship activities of the male. This may be due to her physiological condition, or to some weakness in the courtship sequence, as often occurs when a male of one species courts a female of another species. As long as the female remains in the vicinity of the male but does not allow him to back under her or come into physical contact, the mixed courtship song is the type produced.

If a female leaves a courting male, or another male approaches while a male is courting, he delivers the loud, clear, many-pulse type of chirp (fig. 7, 8) which is also characteristic of the male and female encounters. Sometimes, after producing the full courtship song for a minute or so without success (with the female standing immobile, or at least not moving away), a male will deliver a few of these louder, sharper chirps; turn around and face the female; caress her with his antennae; and begin the mixed courtship singing, slowly turning around and backing toward the female again. If a female withdraws upon being contacted by a courting male, he may deliver a few sharp chirps and then perform the same sequence of activities, or he may merely shift his singing somewhat toward the calling song (that is, by injecting more of the clear, musical pulses which appear now and then in mixed courtship singing) and continue to back toward her.

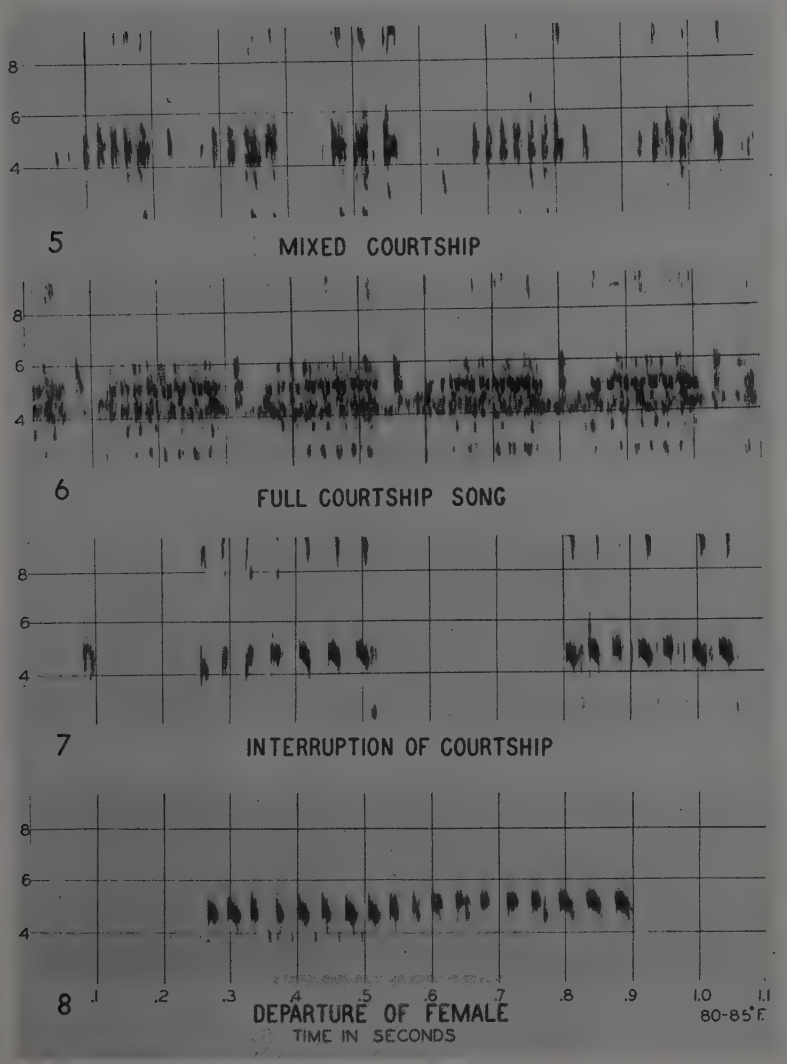
During courtship singing, in addition to backing toward the female, the male sways from side to side and flattens his body against the substrate, especially as he comes into contact with the female. If the female is responsive, she either mounts on top of the male's flattened tegmina, or allows him to back under her, and the spermatophore is transferred in this position. The courtship song either may be necessary for successful copulation, or it may shorten the time between the meeting of the sexes and copulation. It is possible that the motion of the tegmina is more important than the sound produced during courtship. Most of the crickets which do not possess courtship songs have dorsal female-attracting glands which draw the female into the copulatory position. In the tree crickets (Oecanthinae), this gland is located on the metanotum while in the ground crickets (*Nemobius* spp.), it has developed in connection with a spine at the base of the hind tibia.

Magicicada septendecim (*Linnaeus*)[4]
(*Homoptera: Cicadidae: Seventeen-Year Cicada*)

The chief mechanism of sound production in cicadas is well-described by Pringle (1954). Two stiff, convex membranes (tymbals) at the base of the abdomen are alternately buckled inward by the contraction of a pair of large muscles attached to their inner edges, and popped back outward through their own resilience. This action may be compared to dimpling a plastic table tennis ball by pressing it with the thumb and then removing the thumb, thereby allowing the dimpled area to pop back to its normal shape. The drop in pitch near the end of the "Pharoah call" (congregational song, fig. 9) of the seventeen-year cicada corresponds to a lowering of the abdomen, which is slightly elevated during the rest of the call. In many cicadas rapid up-and-down motion of the abdomen provides a secondary pulsation which is superimposed on the more rapid rhythm due to the in-and-out popping of the tymbals.

Unlike the males of singing Orthoptera, male cicadas characteristically do not space themselves apart in the field and remain in one spot all their adult lives.

[4]These observations were made on Brood XIII during June, 1956, in DuPage County, Illinois.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MIXED COURTSHIP
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FULL COURTSHIP SONG
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INTERRUPTION OF COURTSHIP
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.8
.9
1.0
1.1
DEPARTURE OF FEMALE
TIME IN SECONDS
80-85°F.

The congregational songs of male seventeen-year cicadas are produced in series of 1 to 4 songs (rarely more), the insect flying a short distance after each series. Sometimes this flight between song series amounts to no more than a fluttering of the wings which may merely lift the individual from his perch momentarily, and at other times the male may fly several yards to another perch. Caged males rarely sing normally, since they usually strike the cage in these flights, and the rhythm of sing-fly-sing-fly is thus interrupted. Cicada behavior differs further from that of singing Orthoptera in that the males and females congregate into close proximity during the daily singing period. Often so many individuals are crowded together in a small tree or bush that the males are bumping each other continually while singing. Apparently no special male encounter sound has ever been heard in cicadas although on occasions when several males were gathered around a single female, a wing-flipping routine was noticed in which two or more of the males would alternately flip or flutter their wings briefly. This wing-flipping was also noticed in females apparently resisting courting males, and may have a relationship to the short bursts of wing motion between song series which usually result in flight. In some cicadas, a "wing-clacking" sound-producing mechanism occurs in both sexes (Myers, 1929; Pringle, 1954).

Courtship in the seventeen-year cicada consists of the male crawling on the back of the female, extruding his genitalia and moving them about on the ventral surface of the female's abdomen until he is dislodged or the genitalia are engaged. During this time he is producing a distinctive type of sound (fig. 10) which is somewhat analogous to the sound produced by courting male crickets.

Male cicadas produce a third type of sound (fig. 11) when they are disturbed into flight, captured and held, pinched, poked, or otherwise manhandled. This sound is produced by male cicadas captured or chased by birds or cicada-killing wasps. Such "protesting" is known in only a few species of Orthoptera—*Amblycorypha oblongifolia* (DeGeer) (Blatchley, 1920), *Pterophylla camellifolia* (DeGeer), and *Neoconocephalus exiliscanorus* (Davis). It is the best-known sound in most small insects, such as beetles, bugs, caterpillars, leafhoppers, treehoppers, spittlebugs, ants, and velvet ants, probably because such insects are otherwise rarely observed in situations where their soft sounds can be heard.

The moving about by male cicadas during song and the congregation of large numbers of males into close proximity indicates that in cicadas a fundamental difference from orthopteran behavior is that individual females are usually not attracted to individual males by the congregational song. Rather, this sound draws large numbers of individuals of both sexes into close proximity and either the courtship song or some other stimulus is responsible for the pairing of individual males with individual females.

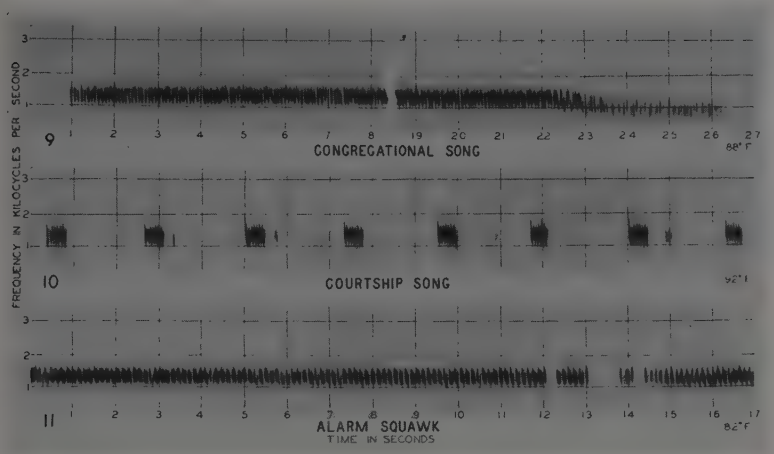
Tetraopes tetrophthalmus *LeConte*
(*Coleoptera: Cerambycidae: Red Milkweed Beetle*)

Relatively little attention has been paid to the sound-producing behavior of the thousands of species of beetles, ants, wasps, flies, moths, butterflies, leafhoppers, treehoppers, spittlebugs, true bugs, and many other small insects that are known either to produce soft sounds, or to possess specialized structures probably associated with sound production or perception. The sounds of most of these insects are so soft that they can be heard only if the insect is practically inside one's ear, or if some sort of amplifying device is set up (Ossianneilsson, 1949; Leston, 1955).

The red milkweed beetle was first noticed by the writer to make a sound when it was picked up and held. The noise made in this situation is a rather noticeable, shrill squeaking (fig. 12), produced by rubbing together stridulatory structures on the back of the pronotum and the front of the mesonotum. Several individuals

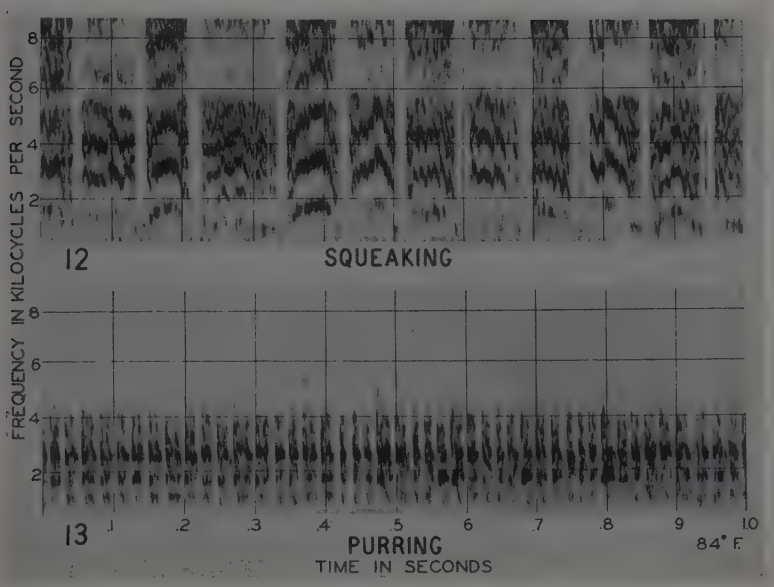
Vibragrams of Sounds of the Seventeen-Year Cicada
Richard D. Alexander

PLATE III



Vibragrams of Sounds of the Red Milkweed Beetle
Richard D. Alexander

PLATE IV



were taken into the laboratory and placed on the leaves and blossoms of milkweed (*Asclepias* sp.) in a quart jar. By listening at the mouth of this jar, one could hear a soft, almost continuous purring noise (fig. 13). A listening cage was set up by fitting a microphone connected to a tape recorder into a large rubber stopper, placing the stopper in a jar containing several beetles, and listening through earphones attached to the tape recorder which was turned to "record" position with the record gain turned up. The sound could be heard very clearly by this method while the beetles were being watched. Apparently both sounds are made by both sexes, and the situations in which they were observed are as follows:

1. When held
   a. between the fingers (squeaking)
   b. inside a closed fist (squeaking and purring)
2. When placed in a small cage
   a. when moving about, or forcing the head down into cracks in corners of the cage (squeaking)
   b. when standing motionless (purring)
3. When caught in a milkweed blossom (squeaking)
4. When placed or fallen on back (squeaking)
5. When fighting (one individual gripping some part of another with its mandibles (squeaking))
6. When two individuals meet and touch antennae or crawl over one another (squeaking or purring)
7. While undisturbed individuals are crawling about and feeding on milkweed leaves and blossoms (purring or squeaking)

Copulatory and pre-copulatory activities were watched several times, and the only time sound production was noticed was when the male was dislodged from the female's back, or the pair fell to the bottom of the jar from their perch on milkweed (squeaking).

It is evident, as already demonstrated by the investigations of Ossianneilsson on sound production in small Auchenorrhyncha (1946, 1949, 1953), that sound may play a complex part in the lives of small insects as well as in large species capable of producing intense sounds which carry great distances. The sounds of the red milkweed beetle are probably not intense enough to draw individuals together from outside the range of senses other than auditory. It is possible, however, that after the adults have assembled on milkweed, perhaps through olfactory attraction, the sounds cause further congregation or are involved in some phase of courtship or sexual selection. The observations recorded here are too scanty to allow more than speculation in this regard.

DISCUSSION

The high degree of differentiation between the sounds made by a given individual insect in different situations, and their consistency, suggests that the structural differences in these sounds are behaviorally significant. Likewise, the fact that no two species of insects, no matter how closely related, have been demonstrated to have inseparable calling or congregational songs, suggests the probability of discriminatory capacity. The writer has tape recordings of about 160 species of insects, representing six orders and fourteen families. All but a few of these can be distinguished by ear alone, and all can be separated by audio-spectrographic analysis. Included in this collection are recordings of several species which are as yet unrecognized by taxonomists because of the lack of observed morphological differences. When such closely related species are sympatric, their calling songs usually differ radically.

Additional observations indicate that structural differences in the calling songs of different species of insects may act as species isolating mechanisms. In the eastern United States, where hundreds of individuals in dozens of different species may be singing simultaneously in a small woodlot or marsh, inability of females to recognize the songs of males of their own species would result in utter confusion. Female tree crickets (*Oecanthus nigricornis* Walker) have been watched by the writer on weeds at night. In several cases the females were noticed to move only when a male two or three feet away on the same plant trilled. Yet, during continuous observations lasting a half hour to an hour, these females often moved only partway to the male, traversing practically every stem and leaf on the way, and moving only when the male trilled. If such a female responded equally to all insect sounds in the area, or even just to the most intense sound in her vicinity, her chances of meeting a male of the same species would be greatly reduced, and the time required would cause this to be a most inefficient communicatory system.

It is well-known that in many species of singing insects neighboring males synchronize or alternate the periodic elements of their songs. This phenomenon can be observed in the field even when such individuals are surrounded or intermixed with singing individuals of other species. Some of the night-singing Orthoptera begin singing in the evening when many species are already singing. When the first individuals begin to sing, the others in a colony chime in so quickly that dozens of individuals may be singing only a few seconds later. In some species, such as *Neoconocephalus nebrascensis* (Bruner), after the first individual in a colony begins to sing, the second individual starts out with his first phrase synchronized with that of the first individual, and each successive individual begins in synchrony with the chorus. This indicates that the near-simultaneous starting of song is not due entirely to a high and uniform degree of sensitivity to climatic condition, but rather to a response of one individual of a species to the beginning of song by another.

Even non-synchronizing species exhibit behavior that can only be explained by an ability to recognize their own sound. In species such as *Atlanticus testaceous* (Scudder), *Amblycorypha oblongifolia* (DeGeer), *Amblycorypha rotundifolia* (Scudder), and *Magicicada cassinii* (Fisher), the individuals do not sing continuously for long periods of time, but instead repeat their phrases only a few times, then are silent for a few minutes before singing again. In the field, different individuals of these species do not sing independently of each other, but rather a colony sings in bursts which are separated by intervals in which none or only a few individuals are singing. This means that these insects must be stimulated by their own sounds rather than by the hundreds of other, often more intense sounds around them.

The answer to the question of discrimination or lack of discrimination with respect to interspecific song differences may be reversed from one situation to the next. In localities where only a very few species are active in song at a given time of day or year, it seems likely that little selective value would be attached to a high degree of specificity to the particular details of structure in the sounds. However, in many species there are strong indications that relatively slight variations in rhythm or speed of pulsation in insect sounds are behaviorally significant.

SUMMARY

A large number and variety of insects produce sound with specialized apparatus. The chief structural variation in insect sounds, and the kind that is apparently behaviorally significant, is in the rhythm and rate of pulsation, or intensity modulation. In many species a variety of sound responses occurs in different situa-

tions, and no two species are known to produce identical sounds in the same situation. It is probable that song differences are important isolating mechanisms between closely related species of Orthoptera and Cicadidae.

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Dictionary of Poisons. *Ibert Mellan* and *Eleanor Mellan.* Philosophical Library, Inc., New York. 1956. 150 pp. $4.75.

The brief histories of certain poisonous chemicals and plants as found throughout the volume are very interesting as is the review of poisons to be found on pages three through seven. A list of substances, arranged alphabetically from Acetanilide to Zinc-containing-compounds, is given, each having the subheadings usually followed by the admonition to call a physician (which should be done first when possible.)

There is a question in the mind of the reviewer as for whom the book was written. Apparently it was not for professional medical personnel, as judged from the nature of the information. In all too many situations the antidote consists of administration of Universal Antidote, followed by an emetic. (The value of Universal Antidote is open to question.) There are some obvious errors and omissions, for example, there is a question about the recommended use of an emetic after bromine or hydrogen peroxide is taken internally. Hydrogen cyanide or hydrocyanic acid is listed with the Acids. The antidotes for acids which follows would be of little or no value; this is also applicable to oxalic acid. Reference is made to the list of materials to be found in the cleaning closet yet no antidotes are to be found for such items as metal polishes and bleaches.

There is a subsection devoted to Barbiturates but the layman does not know which compounds belong to this classification and there are no cross references for specific compounds.

This book will be of value only to laymen trained in First Aid and its use to them is limited.

Loyd E. Harris

THE CARBONATE CONCRETIONS OF THE OHIO SHALE[1]

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INTRODUCTION

Carbonate concretions comprise one of the characteristic features of the Ohio shale. The large spheroids are mentioned in the first geological literature of the state, and a number of theories as to their origin have been proposed. The Ohio shale also contains cone-in-cone structure and small discoid pyrite concretions, but the discussion in this paper is restricted to the carbonate spheroids.

LOCATION

The carbonate concretions are found only in the lower part of the Ohio shale. Located at several horizons, they are most frequent in the lower 50 feet of the formation (Stauffer *et al.*, 1911). Geographically, the concretions are found in a north-south band across central Ohio, wherever the lower part of the Ohio shale is exposed.

Kindle (1912) used the concretions as a stratigraphic marker. He proposed that the name Huron shale be applied to those beds of the Ohio shale in which concretions are found. The Ohio or Huron shale is present from Lake Huron to Kentucky.

CHARACTERISTICS

The carbonate Ohio shale concretions range from 1 to 10 feet in diameter. The smaller ones approach a spherical shape; the larger ones, flattened vertically, are ellipsoidal. The large concretions average 9 feet across and 6 feet in height. Many of these have a funnel-shaped depression in the top and bottom (fig. 1, 2). This depression, viewed in vertical cross section of broken, exposed concretions, creates the impression of double or twinned concretions (fig. 4). The larger concretions often have a ridge around the middle, composed of material different from the main body. The concretions are located along definite stratigraphic horizons. A group exposed at one locality tends to frequent the same horizon. The bedding of the shale arches equally above and below the concretion. This disturbance dies out a few feet on either side of the spheroid. Joints were found passing through some concretions, splitting them.

Cone-in-cone or similar structure typically appears in the outer edges of the concretion. The centers of some exhibit a septarian structure. Horizontal laminae are characteristic features of the main body of the concretion, the bands being one-half inch to several inches thick (fig. 3). The bands are alternating dark and light, the latter containing more chert. At the outer edges the bands curve toward the center plane. This banding is expressed as ridges on the outside of exposed concretions after differential weathering. Some concretions have a concentric ring of marcasite one-half inch thick around the outer edge.

COMPOSITION

The concretionary material typically consists of secondary crystals set in a very fine-grained matrix. The secondary material is usually calcite, dolomite,

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FIGURE 1. (Top) Typical Ohio shale concretion exposed in the quarry in southeast Delaware. Note zoning of concretion and the depression at the top and bottom. (Photo by R. L. Bates.)

FIGURE 2. (Bottom) Closer view of same concretion showing the deformation of the shale bedding. (Photo by R. L. Bates.)

pyrite and silica. The matrix is too finely divided to be identified, but probably contains carbonates, silica and organic matter.

The following chemical analysis of a concretion was made by Demorest for the Ohio Geological Survey (Westgate, 1926).

CO_2	38.83 %
Ca O	27.29
MgO	13.80
SiO_2	9.08
Fe_2O_3	5.03
C (organic)	2.25
Al_2O_3	1.87
S	0.675
MnO_2	0.50
Moisture at 105°C	0.20
TiO	0.12
P_2O_5	trace
	99.645%

The concretion centers contain varied crystal matter. Calcite, fluorite, barite, or celestite may comprise the nucleus of the concretion, although calcite is the most common (Westgate, 1926).

In the heart of larger concretions, the character of the material changes with distance from the center. The center is a soft, gray, porous material containing calcite veinlets. Here laminae are visible only as etched by differential weathering. The material becomes dense, hard, and black several feet from the center. The laminae here are well-defined alternating dark and light bands. These yield a fetid odor when struck, evidence of organic matter. The center material contains occasional rhombs or spherules of calcite or other carbonates. The dark, outer material is nearly all carbonate crystals, forming an interlocking mass. The crystals average 0.1 mm. in size. Detrital quartz fragments may be found throughout the concretion, and bands and patches of chert and chalcedony occur.

Replacement is an important factor in the history of concretions. Most of the crystalline matter is replaced material, and the matrix commonly exhibits large optically oriented patches, probably a product of coarse recrystallization. Plant tissue is often doubly replaced, first by carbonate and then by quartz. Many carbonate rhombs are zoned, indicating successive stages of replacement.

Fossil matter is common in the concretions. Plant spore cases about 0.25 mm. across are common. They consist of tasmanite, a brownish, resinous substance. Those in the center of the concretion are relatively undeformed; away from the center they are crushed between carbonate crystals or included in the crystal. Often those in the center are partially collapsed, probably from osmotic pressure. These spore cases are also abundant in the shale, where they have been flattened into plates.

Ostracods and unidentified spicules are often present in the concretion centers. Fossil wood, usually of an ancient pine, *Dadoxylon newberryi*, lies in the nucleus of some concretions. Well-preserved fish bones also have been found (Orton, 1878). Nearly all fossils are replaced by silica or carbonate.

The concretions have been designated as "ironstone" by several writers (Stauffer *et al.*, 1911). This probably results from pyrite and possibly siderite in the concretion. These weather to limonite, staining the shell of the concretion a typical yellow-brown. The concretions may be best classed as "carbonate" because of the predominance of calcite and dolomite.

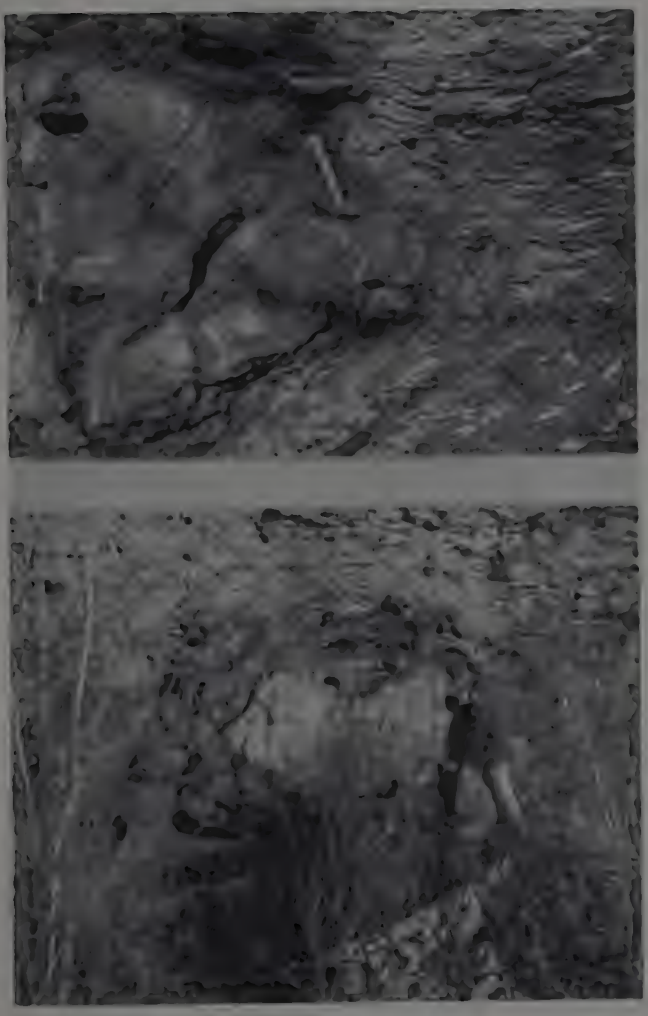

FIGURE 3. (Top) Delaware quarry concretion exhibiting horizontal laminae. (Photo by R. L. Bates.)

FIGURE 4. (Bottom) Concretion in Delaware quarry exhibiting pronounced depression on top and bottom. (Photo by R. L. Bates.)

PREVIOUS THEORIES OF ORIGIN

The origin of concretions is generally a geological puzzle, and the Ohio shale concretions are no exception. First reference to them was made by Newberry (1873). Describing concretions near Worthington, Ohio, he stated they were formed more or less syngenetically with the shale, and the curving of the shale above and below the concretion was caused by shrinkage and compaction of surrounding sediments.

Orton (1878) mentioned these concretions and noted the variety of minerals and fossils often enclosed in them. Orton apparently accepted Newberry's theory of syngenetic origin.

The next reference to the Ohio shale concretions was by Daly (1900), who described and discussed the origin of calcareous concretions at Kettle Point, Ontario. These concretions are in the lower part of the Huron shale (correlative with the Ohio shale). Daly noted that joints did not break the concretions, and the concretions had concentric structure and radial arrangement of crystals. Noting also that the shale arched under as well as over the concretions, he believed them to be epigenetic or secondary forms, the shale being deformed by the mechanical energy of crystallizing calcite. This crystallization was effected by the circulation of ground water within the shale. Daly supposed the joints to be produced by desiccation of the shale, and the concretions to be subsequent to the joints. Because the joints do not break the concretions and because of the radial arrangement of crystals, it is possible that the origin of the Kettle Point concretions is different from that in Franklin County.

In 1921, Richardson reported on experimentation with the deformation of bedding around concretions. On the basis of the experiments, Richardson determined that the conformity of stratification to concretions is caused by displacive growth and that the earliest possible date of formation of the concretion is later than the first compacting of the surrounding sediment. He also believed that the flattened ellipsoidal shape is confined to displacive concretions. He assumed vertical pressure, limiting growth in the vertical direction. His experiments, however, were made by using plastic clay to simulate the material surrounding the concretion. When subjected to vertical pressure, the plastic would flow around the concretion; there would be no shrinking due to de-watering of the sediment.

Although Richardson's experiments were not directed toward the Ohio shale concretions, his results apparently governed the thinking of Ohio geologists on this subject.

Stauffer *et al.*, (1911) mentioned the concretions in a discussion of the Ohio shale. He thought the concretions to be secondary because of the arching of the shale around them and their uniformity of composition.

Westgate (1926) discussed the concretions in detail and wrote that they were "clearly epigenetic." He believed they were related in some way to water circulation just above the impervious Olentangy shale. Why deposition occurred, what limited the size of the concretions, and why they are present only in the lower part of the formation, were questions he could not answer.

Although no further references on the Ohio shale concretions were found, several articles relating to concretions in shale were studied. These discussions favored syngenetic origin, in which the formation of the concretion occurred during or shortly after deposition of the enclosing sediments.

Tarr (1921) wrote that concretions in shale generally have a syngenetic origin. If epigenetic, they should crumple and distort the shale laterally. Tarr had never seen this lateral distortion.

According to those favoring a secondary origin, stratification lines in the concretions are an expression of the shale bedding prior to replacement or dis-

placement by concretionary growth. Tarr believed these lines were independent of the bedding, developing as the concretionary material accumulated. Well preserved, undeformed fossils within the concretions, and concretions of large volume, were also taken as evidence of a syngenetic origin. Both of these features are characteristic of the Ohio shale concretions.

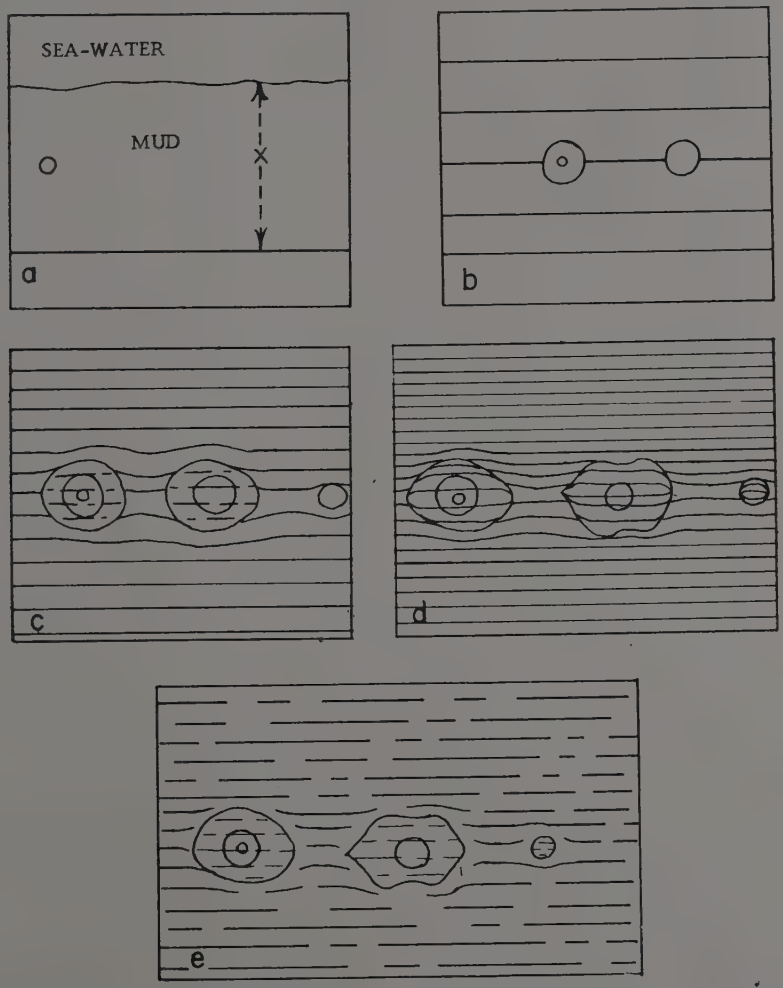

FIGURE 5. a. Sketch of muddy calcite forming in uncompacted mud. X is the original thickness of mud, successively compacted and shrunk in the following diagrams.

b. Concretion forming in partially compacted mud.

c. In more densely compacted mud, some concretions are still beginning to develop. Horizontal laminae of mud frozen in concretion.

d. Compaction of mud halts further concretion growth. Note laminae in edges of concretions curving toward center plane.

e. Ohio shale compacted and consolidated around the concretions. State of concretions today.

The probable inability of ground water to carry enough calcium carbonate through the impervious shale to form the concretion, and the fact that if formed by ground water in uniform shale the concretion would not occur in one bedding plane, were taken as evidence supporting the syngenetic theory.

A problem of the syngenetic theory is the calcium carbonate's forming a concretion rather than a bed. Tarr suggested that this may be due to slower precipitation of the carbonate in the forming of a concretion.

Twenhofel (1932) also discussed concretionary growth. He supported the syngenetic origin of concretions in shale with the same reasoning as Tarr.

It should be noted that both Tarr and Twenhofel used the term syngenetic to designate formation of the concretion during the accumulation of enclosing sediment. Epigenetic applied to growth after the material was buried. The authors favoring the epigenetic origin used the term to mean the formation of the concretion subsequent to the compaction and consolidation of the shale.

PENECONTEMPORANEOUS THEORY OF ORIGIN

Richardson (1921) designated three relative ages at which concretions might form: contemporaneous, penecontemporaneous, and subsequent. Contemporaneous concretions form at the same time and at about the same rate as the enclosing sediment; "contemporaneous" corresponds to "syngenetic" as used by Tarr (1921) and Twenhofel (1932). Penecontemporaneous is defined as formation more or less close to the surface of recently deposited material. Tarr would class such concretions as epigenetic. Subsequent concretions are those forming after deposition when the strata had largely consolidated. These would be classed as epigenetic by Westgate (1926).

The evidence suggests that the Ohio shale concretions are penecontemporaneous (fig. 5). They definitely are not subsequent forms, as they contain undeformed and unoriented spore cases. Spore cases in the shale are flattened and oriented parallel to the bedding. Furthermore, the evidence cited by Tarr to prove that concretions in shale are not subsequent is applicable to the Ohio shale concretions. It is unlikely the concretions are contemporaneous for it is doubtful that shale-forming mud could support a concretion at its surface, *i.e.*, at the water-mud interface.

Thus the formation of the concretions probably occurred during some stage of mud compaction. The water in this mud was strongly charged with minerals, as shown by the collapse of the spore cases due to osmotic pressure. The water in the spore cases diffused out of the cases into areas of higher mineral salt concentration. Crystallization of carbonates would begin around a nucleus, perhaps starting with the replacement of organic matter. From the nucleus, crystallization would move outward forming a crystal lattice. Replacement within this lattice by more carbonates, silica, fluorite, barite, and celestite occurred, forming large crystal masses. After the lattice had formed, the subsequent crystallization away from the center likely drew out water causing shrinkage and septarian structure to develop at the center.

During the early stages of formation of most concretions, compaction of mud probably had produced some orientation of particles. Horizontal laminae passing through the center of most concretions are evidence of this. The growth of the concretion continued outward "freezing" the mud and preserving the orientation as bands. The soft, porous, gray material of the inner part of the concretion was compacted less than the outer, dark, dense crystalline material. Water may have been drawn from the inner material to assist the formation and subsequent replacement in the outer section. This would undoubtedly alter the inside to some degree also.

Replacement continued also as rhombs and spherules of carbonates were formed, and the matrix was replaced by silica. Spore cases often served as the nuclei for the carbonate crystals, while the formation of crystals caught and crushed others.

New concretions formed after the mud was fairly well compacted. Less than two feet in diameter, these contain solid, dense, dark banded material throughout. This material is identical to the outer material of the larger concretions and may be assumed to have formed in the same way.

During the early growth of the concretion, the shape was probably spherical. As compaction increased the orientation of particles in the surrounding mud, the water circulation would tend to become more nearly parallel to the orientation.

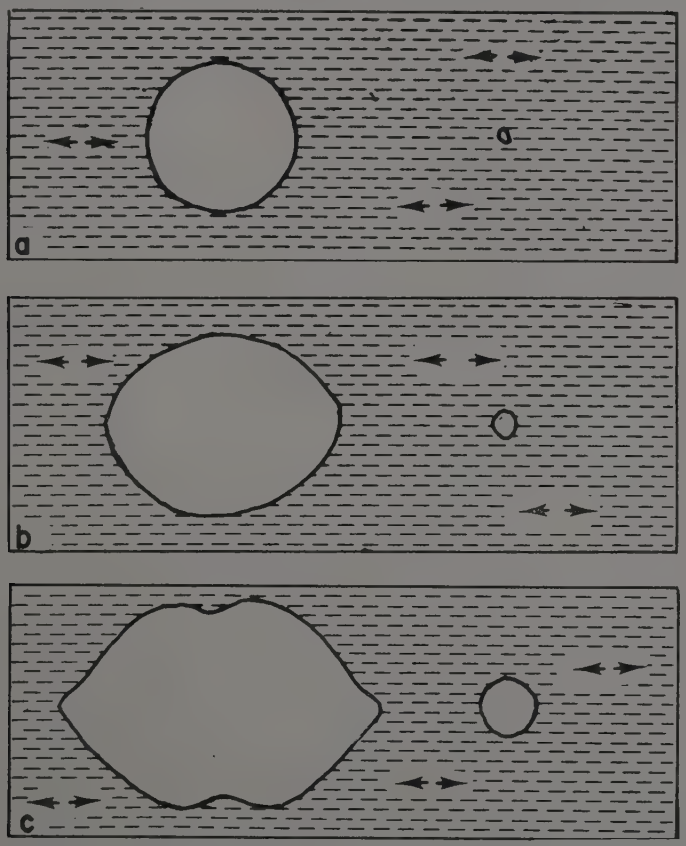

FIGURE 6. a. Systematic diagrams representing growth of two spherical concretions of different size. The view is a cross section. The water circulation is restricted to horizontal movement as shown by the arrows.

b. Additional crystallization is primarily lateral, for horizontally circulating water can not span the large surface area across the top and bottom. Less crystallization would occur here for mineral matter would crystallize on the sides. The small sphere grows equally in all directions.

c. Further crystallization builds up ridges around upper and lower surfaces of large concretions, leaving depressions at very top and bottom. Small concretions remain spherical.

This would give mineral material more access to the sides of the concretion than to the top and bottom. Lateral growth would, therefore, exceed vertical growth and a flattened form would result. This would not greatly affect the smaller concretions, for, with a smaller surface area, charged water could reach all the surface area by diffusion and capillary action. The larger concretions, with a large surface area across the top and bottom, would not receive as much mineral material in these points because it would tend to precipitate on the sides. The smaller the concretion, the more closely it approaches a sphere. In the larger concretions, water circulation would build up material in a ring at the top and bottom, leaving a depression at the very center, since the water reaching this point would have already lost its mineral matter and none would be deposited (fig. 6).

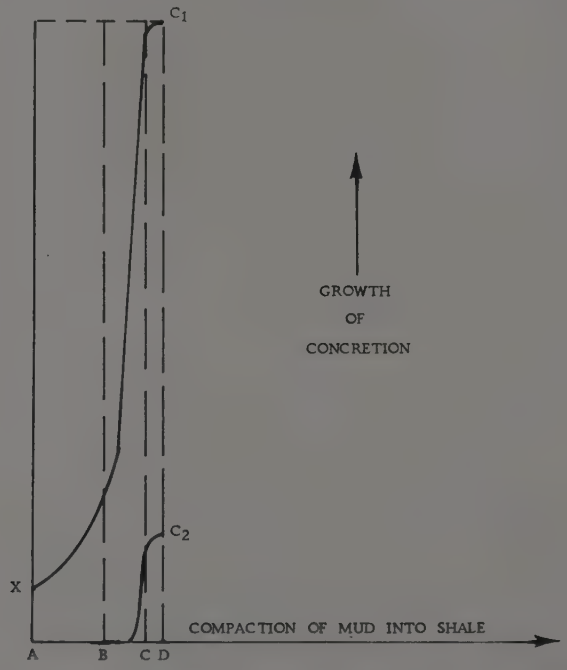

FIGURE 7. Possible range of formation with respect to the compaction of the mud. Curves C_1 and C_2 represent the limits of the range. Along coordinate A, the mud is soupy and uncompacted. The growth of any concretion (up to X) would be crystallization of muddy calcite. A to B on the compaction bar represents that period of compaction when the centers of large concretions were formed. B to C is when the concretion had its greatest growth. Here either the compaction was arrested or the rate of growth was optimum. C to D is the compaction that slowed and finally stopped the growth at D. From D on, the shale was arching over the concretions. C_1 is the curve for the large concretions with muddy calcite centers. C_2 represents small, uniform concretions.

The laminae curving toward the center plane at the edge of the concretion indicates compaction of the mud at the point where the concretion ceased to grow. This probably occurred because the water was squeezed out with compaction. Horizontal rather than convexly curved laminae indicate that the rate of growth

of the concretion did not correspond to the rate of mud compaction (fig. 7). Either the compaction of the mud was arrested, allowing the main part of the concretion to form while the bands remained uniform, or, more likely, the rate of growth was so much faster than the rate of compaction that the laminae are essentially horizontal. This infers that at a certain degree of compaction, conditions for crystal growth were optimum, perhaps with the greatest concentration of mineral salts. Compaction exceeding this optimum would squeeze off water and considerably slow and eventually stop the concretionary growth.

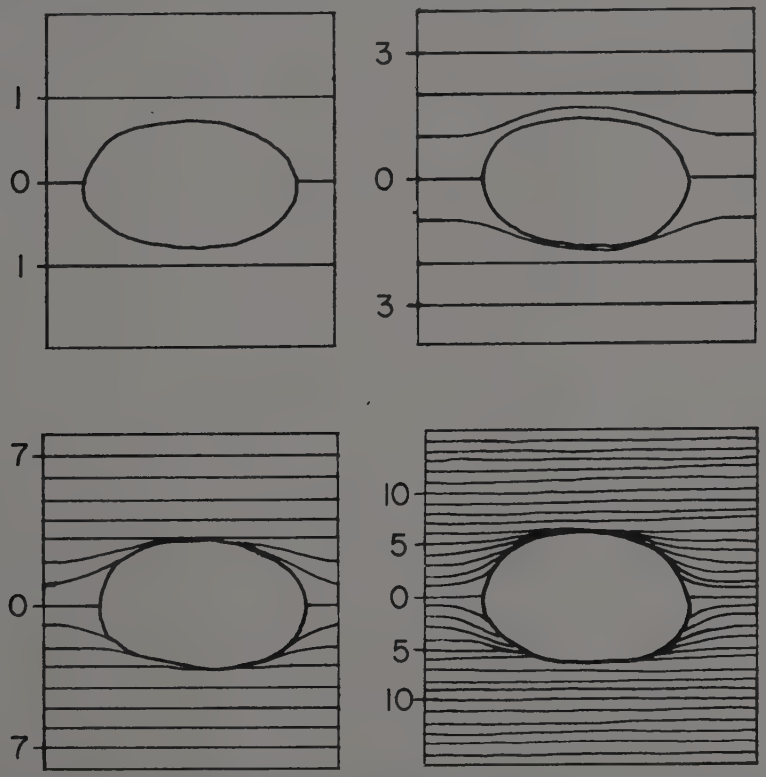

FIGURE 8. Systematic diagram showing compaction and shrinkage of a uniform medium around a solid body. Material reduced to one-eighth original thickness. As distance between lines approaches zero, an increasing number of lines are deformed over the solid body.

At any one time the difference between the compacted mud at the bottom of the concretion and that at the top would have been negligible. Because of the great thickness of sediments and the comparatively small area of the concretion zone, the concretion may be considered to have been formed in a uniform medium. Thus, when final compaction and shrinkage occurred, the mud was arched equally over the top and bottom (fig. 8). The compaction flattened and oriented the spore cases. The horizontal ring found around the middle of some concretions was formed after this, for it contains flattened and oriented spore cases. This material is not directly related to the main body of the concretion, for the ring weathers off exposed surfaces of the concretion, leaving a smooth curved face.

A small amount of growth due to replacement occurred at a later time. Rather than a sharply defined shale-concretion boundary, a gradual transition between the two exists. Some concretions have a small concentric ring of pyrite or marcasite around the outside, resulting from later replacement. Also cone-in-cone structure around the outer edge of some concretions is evidence of later growth. These areas contain no spore cases.

When the joints that cut the Ohio shale were formed, many concretions were broken. This exposure to ground water may have effected still later replacement within the concretion.

The reason for the concretion remains a problem. It may be as Tarr (1921) suggested, that slow precipitation of carbonates promoted concretionary structures instead of beds. Perhaps there was an exceptional amount of soluble material in the mud on the sea bottom. And an irrefutable answer may never be found.

SUMMARY

The Ohio shale concretions are large spheroids in the lower part of the formation. Consisting largely of calcite and dolomite, the concretions contain a great deal of replaced material, especially carbonates and silica. Fossil material is present throughout the concretions. Well preserved animal and plant remains comprise the nuclei of the concretions, and spore cases are present throughout.

Previous theories of origin favor a formation either subsequent to the solidification of the shale or during the deposition of the enclosing sediments. The evidence suggests it is more likely that the concretions formed after the deposition of the enclosing sediments but before complete compaction of the mud. Crystallization began around a nucleus and spread outward. Replacement and secondary growth of crystals were important processes during the development of the concretion. Horizontal banding in the concretion is an expression of the compaction of the mud, frozen by crystallization. Additional compaction, as recorded by laminae bending toward the center plane, squeezed out the water and halted further growth. At a much later time, ground water may have added marcasite rings or caused replacement of the shale near the concretion. Because water in the compacted mud would tend to circulate in horizontal planes, the larger concretions grow faster laterally, resulting in flattened ellipsoids. The small concretions were not affected by this, as the charged water could more easily reach all points on the surface. The arching of the shale above and below the concretion is due to the compaction and shrinkage of the mud around the solid object.

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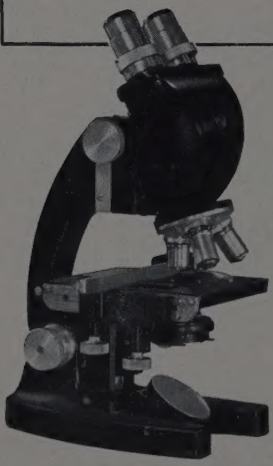

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